An Interop Publication

ConneXions

The Interoperability Report

April 1992 | *Special Issue: Emerging Broadband Services* | Volume 6, No. 4

ConneXions — The Interoperability Report tracks current and emerging standards and technologies within the computer and communications industry.

In this issue:

ConneXions is published monthly by Interop Company, 480 San Antonio Road, Suite 100, Mountain View, CA 94040, USA. 415-941-3399. Fax: 415-949-1779. Toll-free: 1-800-INTEROP.

ISSN 0894–5926

From the Editor

Much has been happening in the area of LAN/WAN interconnection technologies over the last few years. Standards such as Frame Relay, Switched Multimegabit Data Service (SMDS), and other high speed systems are now in the process of becoming offered *services* rather than just technologies "on the drawing board." This month we focus on one particular set of emerging broadband services, namely Broadband ISDN, SONET and ATM. Since all of these technologies are on the "standards track" we've decided to publish them as part of our (never-ending it seems) series *Components of OSI.*

With *Broadband ISDN* (B-ISDN), services such as video, requiring data rates orders of magnitudes beyond those that can be delivered by "vanilla ISDN" will become available. For all information transfer, B-ISDN networks will use *Asynchronous Transfer Mode* (ATM) at the user–network interface. Broadband ISDN and ATM are described in our first article, authored by William Stallings.

Synchronous Optical Network (SONET) is an optical transmission interface originally proposed by Bellcore and standardized by ANSI. SONET is the logical follow-on to today's high-speed wide area telecommunications services such as T1 and T3, but is also intended as a backbone carrier for ATM traffic. Bill Stallings is also the author of this article. Both articles were adapted from his book *ISDN and Broadband ISDN,* which is reviewed at the end of this issue.

Our third article describes Asynchronous Transfer Mode and the so-called "ATM Adaptation Layers" (AALs) in more detail. The article outlines how AALs are used for data transport, and relates this technology to SMDS and to the IEEE 802.6 standards. The article is by George Clapp and Mike Zeug from Ameritech Services.

As mentioned above, we've included a review of Stalling's ISDN textbook as well as one called *Asynchronous Transfer Mode—Solution for Broadband ISDN* by Martin de Prycker. A third book, *Integrated Broadband Networks—An Introduction to ATM-Based Networks* by Rainer Händel & Manfred Huber will be reviewed in a future issue.

Also in this issue is a letter to the Editor from the "Internet Explorer," Carl Malamud. Carl is currently on his third round-the-world trip compiling material for his forthcoming book, *Exploring the Internet,* and we will bring you a couple of reports from his travels in future editions.

INTEROP 92 Spring is only a month a way, so if you haven't done so already, it is time to mail, fax or phone in your registration. For more information, call 1-800-INTEROP or 1-415-941-3399, or fax us at 1-415-949-1779. We look forward to seeing you in Washington.

Components of OSI: Broadband ISDN

by William Stallings, Comp-Comm Consulting

Introduction

The planning for ISDN began as far back as 1976 and is only now moving from the planning stage to prototypes and actual implementations. It will be a number of years before the full spectrum of ISDN services is widely available, and there will continue to be refinements and improvements to ISDN services and network facilities. Nevertheless, with the publication of the 1988 "Blue Book" set of Recommendations from CCITT, the bulk of the work on ISDN is complete. To be sure, future versions of the CCITT standards will provide refinements and enhancements to ISDN. But, since 1988, much of the planning and design effort became directed toward a network concept that will be far more revolutionary than ISDN itself. This new concept has been referred to as *Broadband ISDN* (B-ISDN).

CCITT modestly defines B-ISDN as "a service requiring transmission channels capable of supporting rates greater than the primary rate." Behind this innocuous statement lie plans for a network and a set of services that will have far more impact on business and residential customers than ISDN. With B-ISDN, services, especially video services, requiring data rates orders of magnitudes beyond those that can be delivered by ISDN will become available. These include support for image processing, video, and high-capacity workstations and local area networks (LANs). To contrast this new network and these new services to the original concept of ISDN, that original concept is now being referred to as *Narrowband ISDN.*

In 1988, as part of its I-series of recommendations on ISDN, CCITT issued the first two recommendations relating to B-ISDN: I.113, "Vocabulary of Terms for Broadband Aspects of ISDN," and I.121, "Broadband Aspects of ISDN." [1, 2] These documents represent the level of consensus reached among the participants concerning the future B-ISDN, as of late 1988. They provide a preliminary description and a basis for future standardization and development work.

With both demand (user interest) and supply (the technology for high-speed networking) evolving rapidly, the usual four-year cycle would be fatal to hopes of developing a standardized high-speed network utility. To head off the possibility of a fragmentation of effort and a proliferation of non-standard products and services, CCITT issued an interim set of 1990 Draft Recommendations on B-ISDN. The set of thirteen documents (Table 1) provide, for the first time, a detailed and specific master plan for the broadband revolution. Although much work remains to be done, the 1990 standards are sufficient to allow field trails to follow within a few years of the issue date.

B-ISDN services

The driving force behind B-ISDN is *services*. The services that B-ISDN will support form the set of requirements that the network must satisfy. CCITT classifies the services that could be provided by a B-ISDN into "interactive services" and "distribution services." Interactive services are those in which there is a two-way exchange of information (other than control signaling information) between two subscribers or between a subscriber and a service provider. Distribution services are those in which the information transfer is primarily one way, from service provider to B-ISDN subscriber.

Interactive services

Interactive services are further classified as *conversational, messaging,* and *retrieval*. Conversational services provided for real-time dialogue between a user and an application or a user and a server.

This category encompasses a wide range of applications and data types, including the transmission of video, data, and document. An example of a conversational service that would require higher capacity than can be provided by narrowband ISDN is a remote image application, such as CAD/CAM or the review and manipulation of medical images from a hospital image data base server. Another example is video teleconferencing. Conversational services will place the greatest demand on the network, requiring high throughput and short response time.

Number	Title	Description
I.113	Vocabulary of Terms for Broadband Aspects of ISDN	Defines terms considered essential to the understanding and application of the principles of B-ISDN.
I.121	Broadband Aspects of ISDN	States the basic principles of B-ISDN and indicates the evolution of ISDN required to support advanced services and applications.
I.150	B-ISDN ATM Functional Characteristics	Summarizes the functions of the ATM layer.
I.211	B-ISDN Service Aspects	Serves as a guideline for evolving Recommendations on B-ISDN services. Includes a classification of B-ISDN services an a consideration of necessary network aspects
I.311	B-ISDN General Network Aspects	Describes networking techniques, signaling principles, traffic control, and resources management for B-ISDN. Introduces concepts of transmission path, virtual path, and virtual channel.
I.321	B-ISDN Protocol Reference Model and Its Application	Describes additions to the ISDN protocol reference model needed to accommodate B-ISDN services and functions.
I.327	B-ISDN Functional Architecture	Describes additions to the ISDN functional architecture needed to accommodate B-ISDN services and functions.
I.361	B-ISDN ATM Layer Specification	Describes the ATM layer, including cell structure, cell coding, and ATM protocol.
I.362	B-ISDN ATM Adaptation Layer (AAL) Functional Description	Provides a service classification for AAL and indicates the relationship between AAL services and AAL protocols.
I.363	B-ISDN ATM Adaptation Layer (AAL) Specification	Describes the interactions between the AAL and the next higher layer; the AAL and the ATM layer; and AAL peer-to-peer operations.
I.413	B-ISDN User-Network Interface	Gives the reference configuration for the B-ISDN user-network interface and examples of physical realizations.
I.432	B-ISDN User-Network Interface Physical Layer Specification	Defines physical layer interface for B-ISDN. Includes physical medium specification, timing and framing aspects, and header error control.
I.610	OAM Principles of B-ISDN Access	Describes the minimum functions required to maintain the physical layer and the ATM layer of the customer access.

Table 1: 1990 CCITT Interim Recommendations on Broadband ISDN

Messaging services offer user-to-user communication between individual users via storage units with store-and-forward, mailbox and/or message handling (e.g., information editing, processing and conversion) functions. In contrast to conversational services, messaging services are not in real time. Hence, they place lesser demands on the network and do not require that both users be available at the same time. Analogous narrowband services are X.400 and Teletex. One new form of messaging service that could be supported by ISDN is *video mail,* analogous to today's e-mail (text/graphic) and voice mail.

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Broadband ISDN *(continued)*

Retrieval services enable users to retrieve information stored in information centers, data bases, or libraries of television and film. With this service, a user could order full-length films or videos from a film/video library facility. Of greater interest to business, educational, and medical organizations, the envisioned broadband retrieval service would also allow the retrieval of high-resolution images such as X-ray or computerized axial tomography (CAT) scans, mixed-media documents, and large data files. This service could also be used for remote education and training.

The B-ISDN distribution services are classified into those without and those with user presentation control.

Broadcast services

Distribution services *without* user presentation control are also referred to as *broadcast services.* They provide a continuous flow of information which is distributed from a central source to an unlimited number of authorized receivers connected to the network. Each user can access this flow of information but has no control over it. In particular, the user cannot control the starting time or order of the presentation of the broadcasted information. All users simply tap into the flow of information.

The most common example of this service is broadcast television. Currently, broadcast television is available via radio waves and through cable television distribution systems. With the capacities planned for B-ISDN, this service could be integrated with the other telecommunications services. In addition, higher resolutions can now be achieved and it is anticipated that these higher-quality services will also be available via B-ISDN.

Distribution services *with* user presentation control also distribute information from a central source to a large number of users. However, the information is provided as a sequence of information entities (e.g., *frames*) with cyclical repetition. So, the user has the ability of individual access to the cyclical distributed information and can control start and order of presentation. Due to the cyclical repetition, the information entities, selected by the user, will always be presented from the beginning.

B-ISDN architecture

B-ISDN will differ from a narrowband ISDN in a number of ways. To meet the requirement for high-resolution video, an upper channel rate of on the order of 150Mbps is needed. To simultaneously support one or more interactive services and distributive services, a total subscriber line rate of about 600Mbps is needed. In terms of today's installed telephone plant, this is a stupendous data rate to sustain. The only appropriate technology for widespread support of such data rates is *optical fiber.* Hence, the introduction of B-ISDN depends on the pace of introduction of fiber subscriber loops.

Internal to the network, there is the issue of the switching technique to be used. The switching facility has to be capable of handling a wide range of different bit rates and traffic parameters (e.g., burstiness). Despite the increasing power of digital circuit-switching hardware and the increasing use of optical fiber trunking, it is difficult to handle the large and diverse requirements of B-ISDN with circuit-switching technology. For this reason, there is increasing interest in some type of fast packet switching as the basic switching technique for B-ISDN. This form of switching readily supports a new user–network interface protocol known as *Asynchronous Transfer Mode* (ATM).

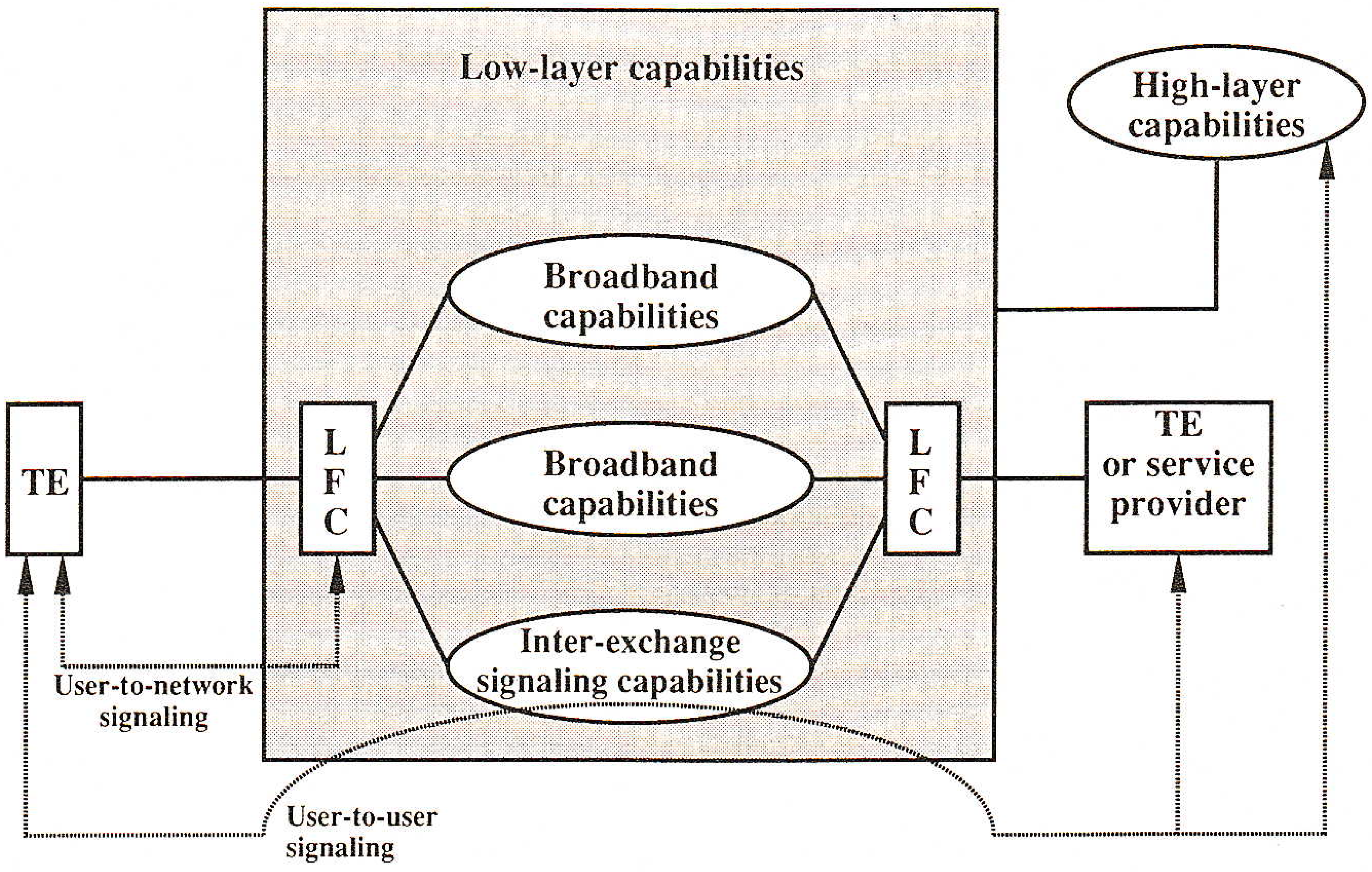

Figure 1: B-ISDN Architecture

Functional architecture

Figure 1 depicts the functional architecture of B-ISDN. As with narrowband ISDN, control of B-ISDN is based on common-channel signaling. Within the network, *Signaling System 7* (SS7), enhanced to support the expanded capabilities of a higher-speed network, will be used. Similarly, the user–network control signaling protocol will be an enhanced version of I.451/Q.931.

B-ISDN must of course support all of the 64Kbps transmission services, both circuit-switching and packet-switching, that are supported by narrowband ISDN. This protects the user's investment and facilitates migration from narrowband to broadband ISDN. In addition, broadband capabilities are provided for higher data rate transmission services. At the user–network interface, these capabilities will be provided with the connection-oriented ATM facility.

Transmission structure

In terms of data rates available to B-ISDN subscribers, three new transmission services are defined. The first of these consists of a full-duplex 155.52Mbps service. The second service defined is asymmetrical, providing transmission from the subscriber to the network at 155.52Mbps, and in the other direction at 622.08Mbps. The highest-capacity service yet defined is a full-duplex 622.08Mbps service.

A data rate of 155.52Mbps can certainly support all of the narrowband ISDN services. That is, it readily supports one or more basic or primary rate interfaces. In addition, it can support most of the B-ISDN services. At that rate, one or several video channels can be supported, depending on the video resolution and the coding technique used. Thus, the full-duplex 155.52Mbps service will probably be the most common B-ISDN service.

The higher data rate of 622.08Mbps is needed to handle multiple video distribution, such as might be required when a business conducts multiple simultaneous videoconferences. This data rate makes sense in the network-to-subscriber direction. The typical subscriber will not initiate distribution services and thus would still be able to use the lower, 155.52Mbps, service. The full-duplex 622.08Mbps service would be appropriate for a video distribution provider.

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Broadband ISDN *(continued)*

The 1988 document (I.121) discussed the need for a 150Mbps and 600Mbps data rate service. The specific rates chosen for the 1990 documents were designed to be compatible with defined digital transmission services. The 1988 document also included a list of specific channel data rates to be supported within these services. The 1990 documents drop all reference to channel rates. This allows the user and the network to negotiate any channel capacity that can fit in the available capacity provided by the network. Thus, B-ISDN becomes considerably more flexible and can be tailored precisely to a wide variety of applications.

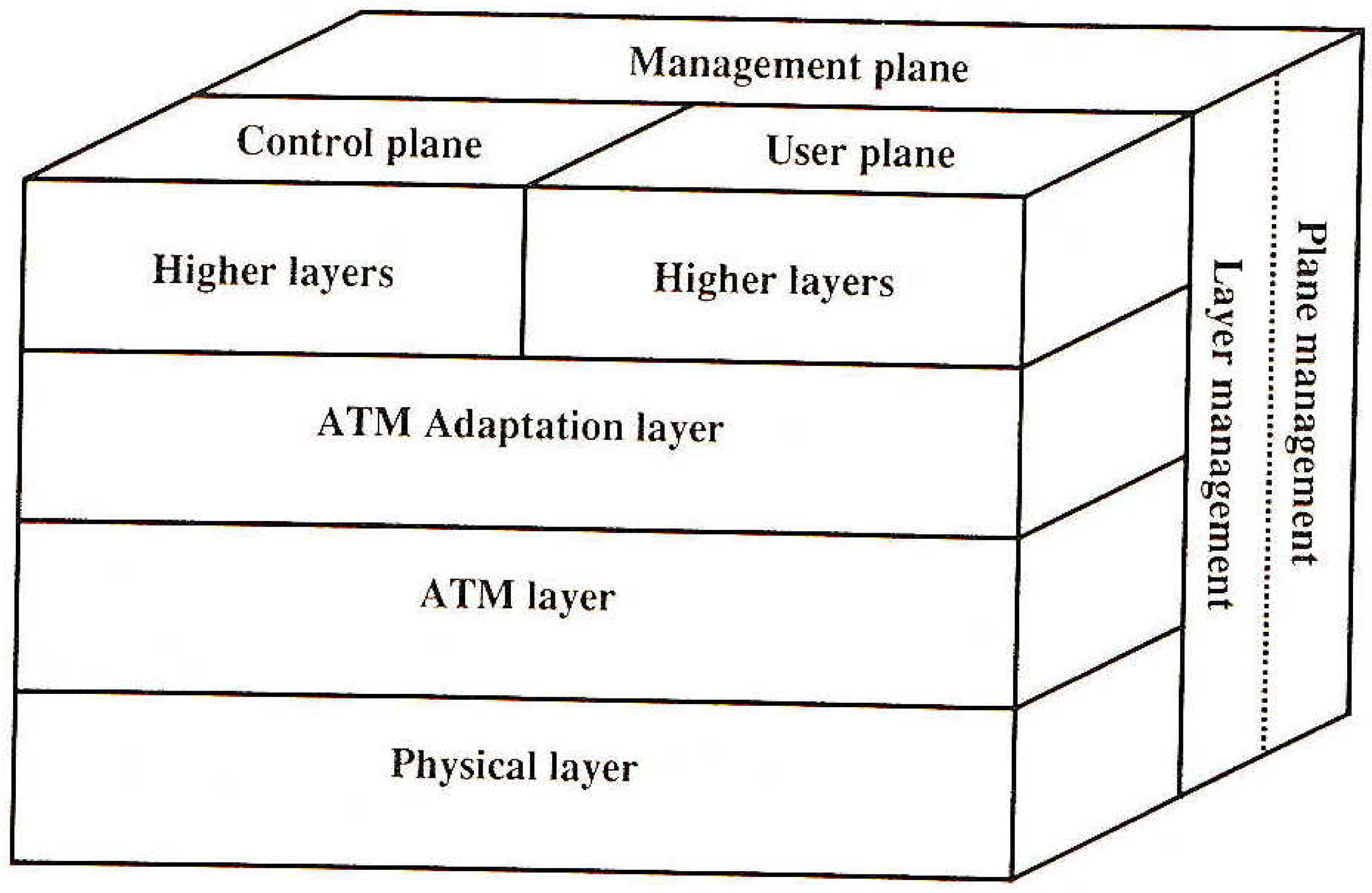

Figure 2: B-ISDN Protocol Reference Model

B-ISDN Protocol Reference Model

The protocol architecture for B-ISDN introduces some new elements not found in the ISDN architecture, as depicted in Figure 2. For B-ISDN, it is assumed that the transfer of information across the user–network interface will use Asynchronous Transfer Mode. ATM is, in essence, a form of packet transmission across the user–network interface in the same way that X.25 [3] is a form of packet transmission across the user–network interface. One difference between X.25 and ATM is that X.25 includes control signalling on the same channel as data transfer, whereas ATM makes use of common-channel signaling. Another difference is that X.25 packets may be of varying length, whereas ATM packets are of fixed size, referred to as "cells."

The decision to use ATM for B-ISDN is a remarkable one. This implies that B-ISDN will be a packet-based network, certainly at the interface and almost certainly in terms of its internal switching. Although the recommendation also states that B-ISDN will support circuit-mode applications, this will be done over a packet-based transport mechanism. Thus, ISDN, which began as an evolution from the circuit-switching telephone network, will transform itself into a packet-switching network as it takes on broadband services.

Adaptation Layer

Two layers of the B-ISDN protocol architecture relate to ATM functions. There is an ATM layer common to all services that provides packet transfer capabilities, and an *ATM Adaptation Layer* (AAL) that is service dependent. The AAL maps higher-layer information into ATM cells to be transported over B-ISDN, then collects information from ATM cells for delivery to higher layers. The use of ATM creates the need for an adaptation layer to support information transfer protocols not based on ATM. Two examples listed in I.121 are PCM voice and LAP-D. PCM voice is an application that produces a stream of bits. To employ this application over ATM, it is necessary to assemble PCM bits into packets (called *cells* in the recommendation) for transmission and to read them out on reception in such a way as to produce a smooth, constant flow of bits to the receiver.

For LAP-D, it is necessary to map LAP-D frames into ATM packets; this will probably mean segmenting one LAP-D frame into a number of packets on transmission, and reassembling the frame from packets on reception. By allowing the use of LAP-D over ATM, all of the existing ISDN applications and control signaling protocols can be used on B-ISDN.

The protocol reference model makes reference to 3 separate planes:

- *User Plane:* Provides for user information transfer, along with associated controls (e.g., flow control and error control).
- *Control Plane:* Performs call control and connection control functions.
- *Management Plane:* Includes *plane management,* which performs management functions related to a system as a whole and provides coordination between all the planes, and *layer management,* which performs management functions relating to resources and parameters residing in its protocol entities.

The 1988 I.121 Recommendation contains the protocol reference model depicted in Figure 2, but provides virtually no detail on the functions to be performed at each layer. The 1990 documents include a more detailed description of functions to be performed, as illustrated in Table 2. Let us examine each of these briefly.

The physical layer consists of two sublayers: the *physical medium sublayer* and the *transmission convergence sublayer.*

CS = Convergence sublayer
SAR = Segmentation and reassembly sublayer
AAL = ATM adaptation layer
ATM = Asynchronous transfer mode
TC = Transmission control sublayer
PM = Physical medium sublayer

Layer Management	Higher Layer Functions	Higher Layers	
	Convergence	CS	AAL
	Segmentation and reassembly	SAR	
	Generic flow control Cell header generation/extraction Cell VPI/VCI translation Cell multiplex and demultiplex	ATM	
	Cell rate decoupling HEC header sequence generation/verification Cell delineation Transmission frame adaptation Transmission frame generation/recovery	TC	Physical layer
	Bit timing Physical medium	PM	

Table 2: Functions of the B-ISDN Layers

Physical Medium Sublayer

The *Physical Medium Sublayer* includes only physical medium dependent functions. Its specification will therefore depend on the medium used. One function common to all medium types is bit timing. This sublayer is responsible for transmitting/receiving a continuous flow of bits with associated timing information to synchronize transmission and reception.

The 1988 document (I.121) does not address the issue of the physical medium on the subscriber's premises. In contrast, the 1990 documents provide preliminary specifications of the medium for the interface between the user and B-ISDN.

For the full-duplex 155.52Mbps service, either coaxial cable or optical fiber may be used. The coaxial cable is to support connections up to a maximum distance of 100 to 200 meters, using one cable for transmission in each direction. The parameters defined in the 1988 Recommendation G.703 are to be used.

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Broadband ISDN *(continued)*

Optical fiber is to support connections up to a maximum distance of 800 to 2000 meters. The details of the optical media (e.g., single mode versus multimode, single full-duplex fiber versus dual fiber) have been postponed for further study.

For a service that includes the 622.08Mbps rate in one or both directions, optical fiber is to be used. Again, the details of the fiber parameters are left for further study.

Transmission Convergence Sublayer

The *Transmission Convergence Sublayer* is responsible for the following functions:

- *Transmission frame generation and recovery:* Transmission at the physical layer consists of frames, such as we saw in the basic and primary rate interfaces. This function is concerned with generating and maintaining the frame structure appropriate for a given data rate.
- *Transmission frame adaptation:* Information exchange at the ATM layer is a flow of ATM cells. This sublayer is responsible for packaging these cells into a frame. One option is to have no frame structure but to simply transmit and receive a flow of cells.
- *Cell Delineation:* For transmission purposes, the bit flow may be scrambled. This sublayer is responsible for maintaining the cell boundaries so that cells may be recovered after descrambling at the destination.
- *HEC Sequence Generation and Cell Header Verification:* Each cell header is protected by a header error control (HEC) code. This sublayer is responsible for generating and checking this code.
- *Cell Rate Decoupling:* This includes insertion and suppression of idle cells in order to adapt the rate of valid ATM cells to the payload capacity of the transmission system.

A key issue at this sublayer is the transmission structure to be used to multiplex cells from various virtual channels. The 1988 document discussed this issue in general terms and proposed three alternatives. For the 155.52Mbps data rate, the 1990 documents reduce the number of options to two and provide more detail. For the 622.08Mbps data rate, the multiplex structure is left for further study.

HEC

The first of the two options for the 155.52Mbps data rate is the use of a continuous stream of cells, with no multiplex frame structure imposed at the interface. Synchronization is on a cell-by-cell basis. That is, the receiver is responsible for assuring that it properly delineates cells on the 53-octet cell boundaries. This task is accomplished by using the *header error control* (HEC) field. As long as the HEC calculation is indicating no errors, it is assumed that cell alignment is being properly maintained. An occasional error does not change this assumption. However, a string of error detections would indicate that the receiver is out of alignment, at which point it performs a hunting procedure to recover alignment.

SDH

The second option is to place the cells in a synchronous time-division multiplex envelope. In this case, the bit stream at the interface has an external frame based on the *Synchronous Digital Hierarchy* (SDH) defined in Recommendation G.709. In the U.S., this frame structure is referred to as SONET (*Synchronous Optical Network*). The SDH frame may be used exclusively for ATM cells or may also carry other bit streams not yet defined in B-ISDN.

The SDH standard defines a hierarchy of data rates, all of which are multiples of 51.84Mbps, and including 155.52Mbps and 622.08Mbps. Therefore, the SDH scheme could also be used to support the higher B-ISDN data rate. However, the 1990 specification does not address this possibility.

As noted, B-ISDN will use ATM, making it a packet-based network at the user interface and almost certainly also in terms of its internal switching. Although the basic nature of B-ISDN is packet-switching, the recommendation also states that it will support circuit-mode applications. Thus, ISDN, which began as an evolution from the circuit-switching telephone networks, will transform itself into a packet-switching network as it takes on broadband services.

ATM Layer

ATM is similar in concept to Frame Relay [4], a packet interface technique planned to be used in narrowband ISDN and available today in some products that transmit over dedicated T-1 circuits. Both ATM and Frame Relay use a streamlined set of functions to provide maximum throughput, taking advantage of the reliability and fidelity of modern digital networks to provide high-speed packet-switching by avoiding repeated error checking and other protocol functions. ATM takes this streamlining process much further than Frame Relay to be able to exploit transmission channels in the tens and hundreds of megabits per second. In contrast to the variable-length frames used in Frame Relay, ATM uses fixed-length cells and is often referred to as *cell relay*.

In ATM, transmission capacity is assigned to a connection based on subscriber requirements and available capacity. Data transfer is connection oriented, using the concepts similar to the *virtual circuit* in X.25.

ATM uses two connection concepts: *virtual path* and *virtual channel*. A virtual channel, much like an X.25 virtual circuit, provides a logical packet connection between two users. A virtual path defines a route from source to destination through a network. Multiple virtual channels may be bundled together to use the same virtual path.

The use of two connection concepts has certain advantages. For one thing, much of the work of setting up connections is done when a virtual path is first established. The addition of a new virtual channel to an existing virtual path requires little overhead. In addition, a number of data transport functions, such as flow control, can be done at the virtual-path level, simplifying the network architecture.

<table>
<tr><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th></tr>
<tr><td colspan="4">Generic flow control</td><td colspan="4">Virtual path identifier</td></tr>
<tr><td colspan="4">Virtual path identifier</td><td colspan="4">Virtual channel identifier</td></tr>
<tr><td colspan="8">Virtual channel identifier</td></tr>
<tr><td colspan="4">Virtual channel identifier</td><td colspan="2">Payload type</td><td>Reserved</td><td>Cell loss priority</td></tr>
<tr><td colspan="8">Header error control</td></tr>
</table>

Figure 3: ATM cell format at User–Network interface

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Broadband ISDN *(continued)*

The ATM cell

Each ATM cell consists of a 5-octet header and a 48-octet information field. The format for the header at the user–network interface is shown in Figure 3 on the previous page. The header includes the following fields:

- *Generic flow control:* This field is to be used for end-to-end flow control between ATM users. Its specific use is not defined but is left for further study.
- *Virtual path identifier:* Identifies the path or route between source and destination.
- *Virtual channel identifier:* Defines a logical connection between two ATM users.
- *Payload type:* Type 00 is for user information; that is, for information from the next higher layer. Other values are not defined but are left for further study. Presumably, network management and maintenance values will be assigned.
- *Cell loss priority:* A value of 1 means that this cell is subject to being discarded, whereas a value of 0 indicates a higher-priority application for which discarding is inappropriate. Discarding might occur in the case of high network congestion.
- *Header error control:* This is an 8-bit error code that can be used to correct single-bit errors in the header and to detect double-bit errors.

All of the details just described are new to the 1990 draft Recommendations. In the 1988 document, the header fields and header size were undefined, and it had not yet been decided to use fixed-size cells.

ATM Adaptation Layer (AAL)

The use of ATM creates the need for an adaptation layer to support information transfer protocols not based on ATM. Two examples listed in the 1988 Recommendation are PCM (Pulse Code Modulation) voice, and the standard data link control protocol for ISDN, *Link Access Protocol-D* (LAP-D).

PCM voice is an application that produces a stream of bits from a voice signal. To use this application over ATM, it is necessary to assemble PCM bits into cells for transmission and to read them out on reception in such a way as to produce a smooth, constant flow of bits to the receiver.

To carry LAP-D signaling across the network, it is necessary to map LAP-D frames into ATM cells. This procedure will probably involve segmenting one LAP-D frame into a number of cells on transmission, and reassembling the frame from cells on reception. By allowing the use of LAP-D over ATM, all of the existing ISDN applications and control signaling protocols can be used on B-ISDN.

Four service classes

The 1988 Recommendation briefly mentions AAL and points out its functions of mapping information into cells and performing segmentation and reassembly. The 1990 documents provide greater detail of the functions and services of this layer. In the area of services, four classes of service are defined (Table 3). The classification is based on whether a timing relationship must be maintained between source and destination, whether the application requires a constant bit rate, and whether the transfer is connection-oriented or connectionless.

	Class A	Class B	Class C	Class D
Timing relation between source and destination	Required		Not Required	
Bit rate	Constant	Variable		
Connection mode	Connection-oriented			Connec-tionless

Table 3: Service Classification for ATM Adaption Layer (I.362)

An example of a class A service is circuit emulation. In this case a constant bit rate, which requires the maintenance of a timing relation, is used, and the transfer is connection-oriented.

An example of a class B service is variable-bit-rate video, such as might be used in a teleconference. Here, the application is connection-oriented and timing is important, but the bit rate varies depending on the amount of activity in the scene.

Classes C and D correspond to data transfer applications. In both cases, the bit rate may vary and no particular timing relationship is required; differences in data rate are handled by the end systems using buffers. The data transfer may be either connection-oriented (class C) or connectionless (class D).

To support these various classes of service, a set of protocols at the AAL level are defined. In the 1990 version, a preliminary definition is provided, which is primarily functional. However, the document does include some detail concerning header formats and procedures. The details of the AAL protocols remain to be worked out.

The future direction of ISDN

Since the publication of the 1988 Blue Book, the central focus of CCITT has been the development of specifications for B-ISDN. B-ISDN is based on a fast packet-switching technology namely ATM. ATM specifies the manner in which data is to be structured for transmission over virtual channels. To accommodate a variety of applications, the ATM adaptation layer (AAL) provides a mapping from various application transfer techniques to ATM. The physical medium to be used on the subscriber's premises can be either coaxial cable or optical fiber, depending on data rate and distance requirements.

Although many issues remain to be resolved, the network architecture and supported services for broadband ISDN are beginning to solidify with the publication of the 1990 draft Recommendations for B-ISDN. Sufficient detail now exists for both providers and users to begin to plan for the arrival of this exciting new network facility.

[This article is based on material in Bill Stallings' *ISDN and Broadband ISDN,* Second Edition, ISBN 0-02-415475-X, Copyright © 1992 by Macmillan Publishing Company. Used with permission. —*Ed.*]

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[1] CCITT Blue Book: "I.113 Vocabulary of Terms for Broadband Aspects of ISDN," 1988.

[2] CCITT Blue Book: "I.121 Broadband Aspects of ISDN," 1988.

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Broadband ISDN *(continued)*

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"Components of OSI" in *ConneXions*

ConneXions has been running a number of articles under the heading "Components of OSI." Here is a list of them:

Integrated Services Digital Network (ISDN)	April	1989
X.400 Message Handling System	May	1989
X.500 Directory Services	June	1989
The Transport Layer	July	1989
Routing overview	August	1989
IS–IS Intra-Domain Routing	August	1989
ES–IS Routing	August	1989
The Session Service	September	1989
Connectionless Network Protocol (CLNP)	October	1989
The Presentation Layer	November	1989
A taxonomy of the players	December	1989
The Application Layer Structure	January	1990
File Transfer, Access, and Management (FTAM)	April	1990
The Security Architecture	August	1990
Group Communication	September	1990
X.25—the Network, Data Link, & Physical Layers	December	1990
The Virtual Terminal ASE	January	1991
Systems Management	April	1991
CO/CL Interworking	May	1991
Open/Office Document Architecture (ODA)	August	1991
Abstract Syntax Notation One (ASN.1)	January	1992
Broadband ISDN, ATM and SONET	April	1992
Inter-Domain Routing Protocol (IDRP)	*Coming soon*	
OSI Conformance Testing	*Coming soon*	

Also note that FDDI, while not published under the same heading, is also an ISO protocol and should be considered part of the set. You'll find articles on FDDI in the October 1990, September 1991 and October 1991 issues. All back issue are available for purchase. There are still more articles to come in this series, so stay tuned!

Components of OSI: Synchronous Optical Network (SONET)

by William Stallings, Comp-Comm Consulting

Introduction

Synchronous Optical Network (SONET) is an optical transmission interface originally proposed by Bellcore and standardized by ANSI. A compatible version, referred to as *Synchronous Digital Hierarchy* (SDH), has been published by CCITT in Recommendations G.707, G.708, and G.709. (In what follows, we will use the term "SONET" to refer to both specifications. Where differences exist, these will be addressed). SONET is intended to provide a specification for taking advantage of the high-speed digital transmission capability of optical fiber.

The SONET standard addresses the following specific issues:

- Establishes a standard multiplexing format using any number of 51.84Mbps signals as building blocks. Because each building block can carry a DS3 signal, a standard rate is defined for any high-bandwidth transmission system that might be developed.
- Establishes an optical signal standard for interconnecting equipment from different suppliers.
- Establishes extensive Operations, Administration, and Maintenance (OAM) capabilities as part of the standard.
- Defines a synchronous multiplexing format for carrying lower level digital signals (DS1, DS2, CCITT standards). The synchronous structure greatly simplifies the interface to digital switches, digital cross-connect switches, and add-drop multiplexers.
- Establishes a flexible architecture capable of accommodating future applications such as Broadband ISDN with a variety of transmission rates.

Driving forces

Three key requirements have driven the development of SONET. First was the need to push multiplexing standards beyond the existing DS3 (44.736Mbps) level. With the increasing use of optical transmission systems, a number of vendors have introduced their own proprietary schemes of combining anywhere from 2 to 12 DS3s into an optical signal. In addition, the European schemes, based on the CCITT hierarchy are incompatible with North American schemes. SONET provides a standardized hierarchy of multiplexed digital transmission rates that accommodates existing North American and CCITT rates.

A second requirement was to provide economic access to small amounts of traffic within the bulk payload of an optical signal. For this purpose, SONET introduces a new approach to time-division multiplexing. We address this issue below when we examine the SONET frame format.

A third requirement is to prepare for future sophisticated service offerings, such as virtual private networking, time-of-day bandwidth allocation, and support of the Broadband ISDN ATM transmission technique. To meet this requirement, a major increase in network management capabilities within the synchronous time-division signal were needed.

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SONET *(continued)*

Signal Hierarchy

The SONET specification defines a hierarchy of standardized digital data rates (Table 1). The lowest level, referred to as STS-1 (*Synchronous Transport Signal level 1*) or OC-1 (*Optical Carrier level 1*) is 51.84Mbps. (An OC-N rate is the optical equivalent of an STS-N electrical signal. End user devices transmit and receive electrical signals; these must be converted to and from optical signals for transmission over optical fiber). This rate can be used to carry a single DS3 signal or a group of lower-rate signals, such as DS1, DS1C, DS2, plus CCITT rates.

Multiple STS-1 signals can be combined to form an STS-N signal. The signal is created by interleaving bytes from *N* STS-1 signals that are mutually synchronized.

SONET Designation	CCITT Designation	Data Rate (Mbps)
STS-1/OC-1		51.84
STS-3/OC-3	STM-1	155.52
STS-9/OC-9	STM-3	466.56
STS-12/OC-12	STM-4	622.08
STS-18/OC-18	STM-6	933.12
STS-24/OC-24	STM-8	1244.16
STS-36/OC-36	STM-12	1866.24
STS-48/OC-48	STM-16	2488.32

Table 1: SONET/SDH Signal Hierarchy

For the CCITT Synchronous Digital Hierarchy, the lowest rate is 155.52Mbps, which is designated *STM-1*. This corresponds to SONET STS-3. The reason for the discrepancy is that STM-1 is the lowest-rate signal that can accommodate a CCITT level 4 signal (139.264Mbps).

System Hierarchy

SONET capabilities have been mapped into a four-layer hierarchy (Figure 1):

- *Photonic:* This is the physical layer. It includes a specification of the type of optical fiber that may be used and details such as the required minimum powers and dispersion characteristics of the transmitting lasers and the required sensitivity of the receivers. This layer is also responsible for converting STS (electrical) signals to OC (optical) signals.
- *Section:* This layer creates the basic SONET frames. Transmission functions include framing, scrambling, and error monitoring.
- *Line:* This layer is responsible for synchronization, multiplexing of data onto the SONET frames, and protection switching.
- *Path:* This layer is responsible for end-to-end transport of data at the appropriate signaling speed.

Figure 1b shows the physical realization of the logical layers. A *section* is the basic physical building block and represents a single run of optical cable between two optical fiber transmitter/receivers. For shorter runs, the cable may run directly between two end units. For longer distances, regenerating *repeaters* are needed. The repeater is a simple device that accepts a digital stream of data on one side and regenerates and repeats each bit out the other side.

Issues of synchronization and timing need to be addressed. A *line* is a sequence of one or more sections such that the internal signal or channel structure of the signal remains constant. End points and intermediate switches/multiplexers that may add or drop channels terminate a line. Finally, a *path* connects to end terminals; it corresponds to an end-to-end circuit. Data is assembled at the beginning of a path and is not accessed or modified until it is disassembled at the other end of the path.

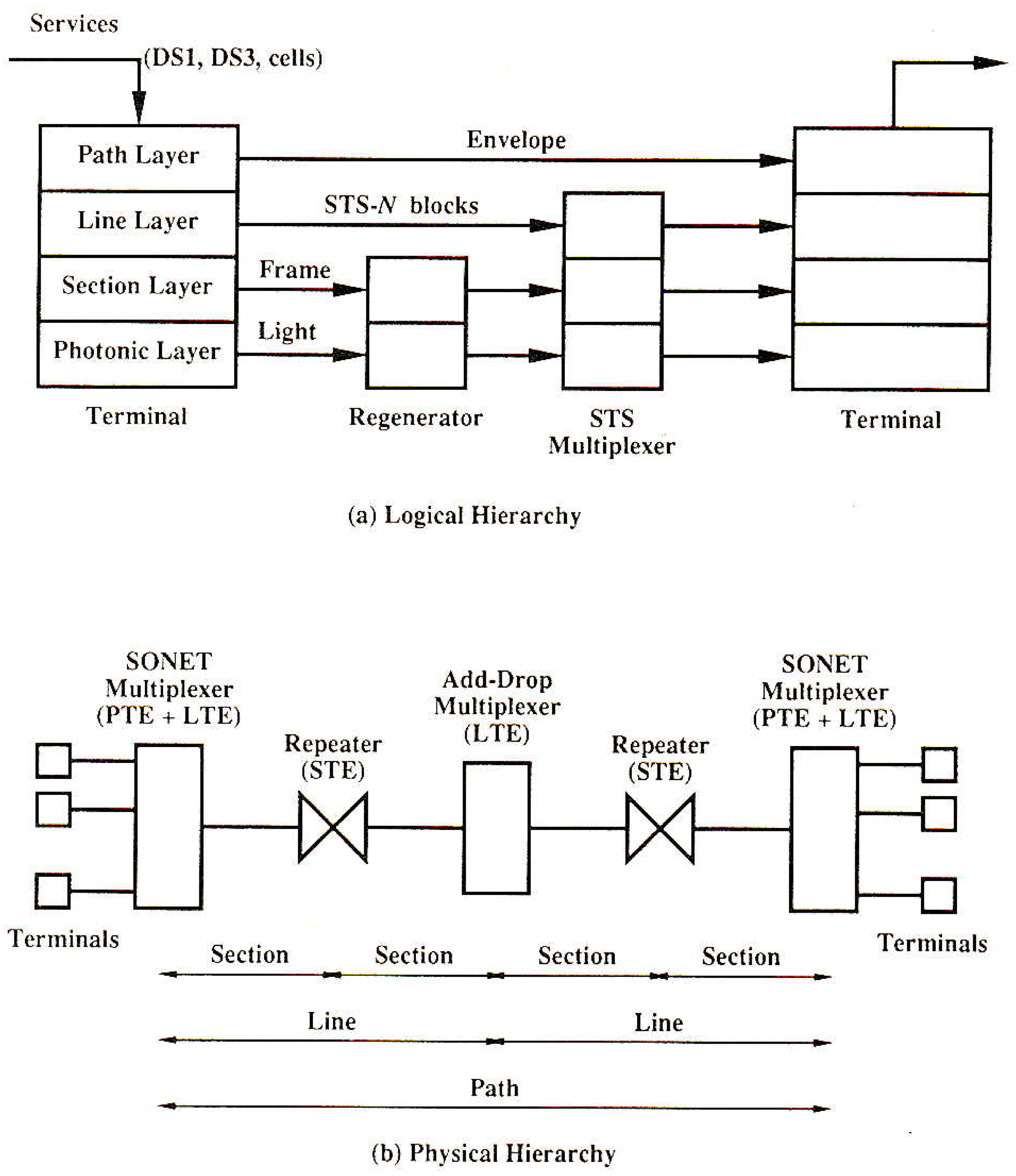

Figure 1: SONET System Hierarchy

Frame format

The basic SONET building block is the STS-1 frame, which consists of 810 octets and is transmitted once every 125μs, for an overall data rate of 51.84Mbps (Figure 2a). The frame can logically be viewed as a matrix of 9 rows of 90 octets each, with transmission being one row at a time, from left to right and top to bottom.

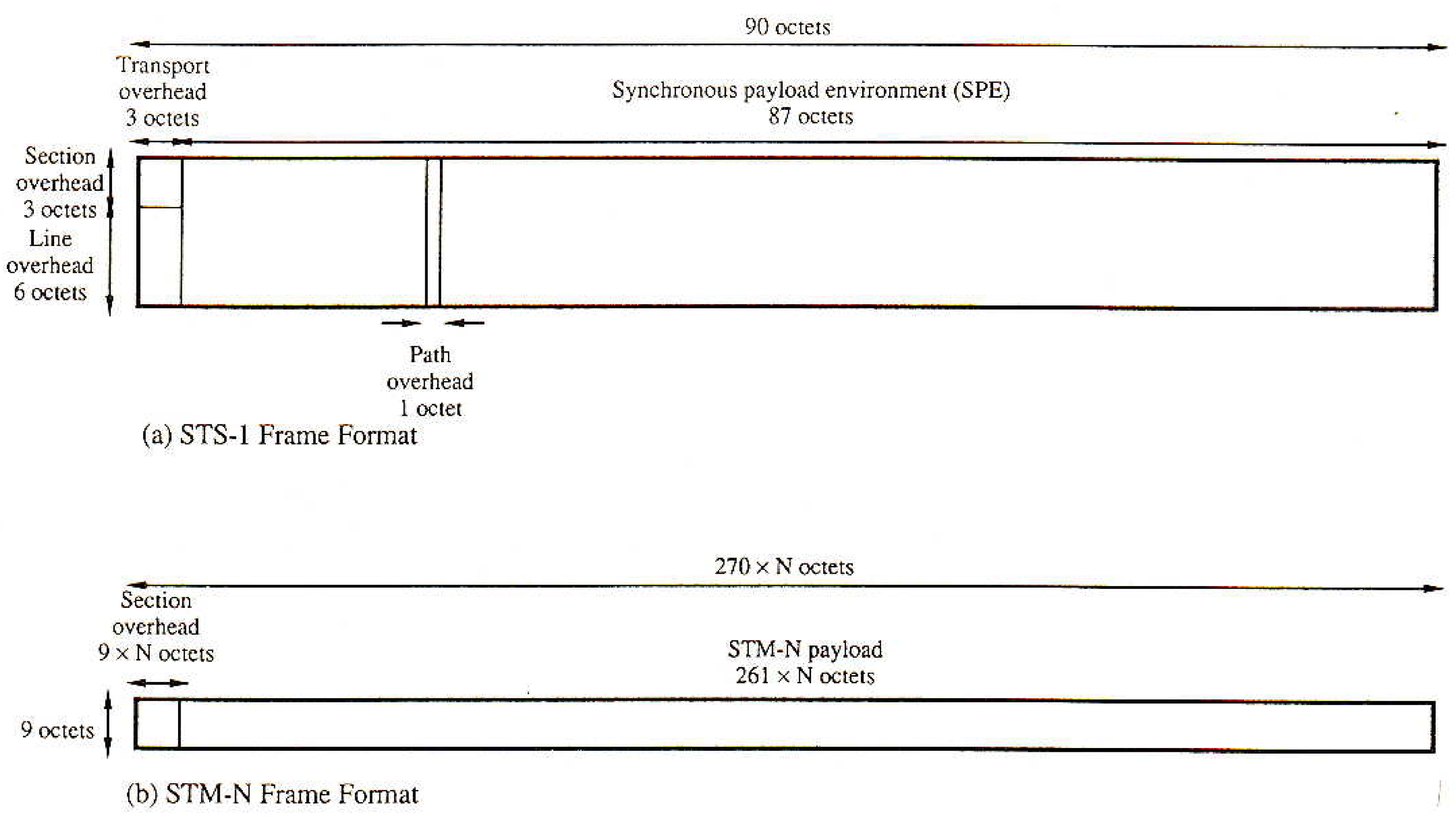

Figure 2: SONET/SDH Frame formats

The first three columns (3 octets x 9 rows = 27 octets) of the frame are devoted to overhead octets. Nine octets are devoted to section-related overhead and 18 octets are devoted to line overhead. Figure 3a shows the arrangement of overhead octets, and Table 2 defines the various fields.

continued on next page

SONET *(continued)*

The remainder of the frame is *payload,* which is provided by the path layer. The payload includes a column of path overhead, which is not necessarily in the first available column position; the line overhead contains a pointer that indicates where the path overhead starts. Figure 3b shows the arrangement of path overhead octets, and Table 2 defines these. Figure 2b shows the general format for higher-rate frames, using the CCITT designation.

Section Overhead	Framing A1	Framing A2	STS-ID C1
	BIP-8 B1	Orderwire E1	User F1
	Data Com D1	Data Com D2	Data Com D3
Line Overhead	Pointer H1	Pointer H2	Pointer Action H3
	BIP-8 B2	APS K1	APS K2
	Data Com D4	Data Com D5	Data Com D6
	Data Com D7	Data Com D8	Data Com D9
	Data Com D10	Data Com D11	Data Com D12
	Growth Z1	Growth Z2	Orderwire E2

(a) Section Overhead

Trace J1
BIP-8 B3
Signal Label C2
Path Status G1
User F2
Multiframe H4
Growth Z3
Growth Z4
Growth Z5

(b) Path Overhead

Figure 3: SONET STS-1 Overhead Octects

Pointer adjustment

In conventional circuit-switched networks, most multiplexers and telephone company channel banks require the demultiplexing and remultiplexing of the entire signal just to access a piece of information that is addressed to a node. For example, consider that T-1 multiplexer *B* receives data on a single T-1 circuit from T-1 multiplexer *A* and passes the data on to Multiplexer *C*. In the signal received, a single DS0 channel (64Kbps) is addressed to node *B*. The rest will pass on to node *C* and further on into the network. To remove that single DS0 channel, *B* must demultiplex every bit of the 1.544Mbps signal, remove the data, and remultiplex every bit. A few proprietary T-1 multiplexers allow for *drop-and-insert* capability, meaning that only part of the signal has to be demultiplexed and remultiplexed, but this equipment will not communicate with that of other vendors.

SONET offers a standard drop-and-insert capability, and it applies not just to 64Kbps channels but to higher data rates as well. SONET makes use of a set of pointers that locates channels within a payload and the entire payload within a frame, so that information can be accessed, inserted, and removed with a simple adjustment of pointers. Pointer information is contained in the path overhead that refers to the multiplex structure of the channels contained within the payload. A pointer in the line overhead serves a similar function for the entire payload. We examine the use of this latter pointer in the remainder of this section.

SPE

The *synchronous payload environment* (SPE) of an STS-1 frame can float with respect to the frame. The actual payload (87 columns x 9 rows) can straddle two frames (Figure 4). The H1 and H2 octets in the line overhead indicate the start of the payload.

	Section Overhead
A1, A2:	Framing bytes = F6,28 hex; used to synchronize the beginning of the frame.
C1:	STS-1 ID identifies the STS-1 number (1 to N) for each STS-1 within an STS-*N* leaved parity byte providing even parity over previous STS-*N* frame after scrambling; the ith bit of this octet contains the even parity value calculated from the ith bit position of all octets in the previous frame.
E1:	Section level 64Kbps PCM orderwire; optional 64Kbps voice channel to be used between section terminating equipment, hubs, and remote terminals.
F1:	64Kbps channel set aside for user purposes.
D1-D3:	192Kbps data communications channel for alarms, maintenance, control, and administration between sections.
	Line Overhead
H1-H3:	Pointer bytes used in frame alignment and frequency adjustment of payload data.
B2:	Bit-interleaved parity for line level error monitoring.
K1, K2:	Two byes allocated for signaling between line level automatic protection switching equipment; uses a bit-oriented protocol that provides for error protection and management of the SONET optical link.
D4-D12:	576Kbps data communications channel for alarms, maintenance, control, monitoring, and administration at the line level.
Z1, Z2:	Reserved for future use.
E2:	64Kbps PCM voice channel for line level orderwire.
	Path Overhead
J1:	64Kbps channel used to repetitively send a 64-octet fixed-length string so a receiving terminal can continuously verify the integrity of a path; the contents of the message are user programmable.
B3:	Bit-interleaved parity at the path level, calculated over all bits of the previous SPE.
C2:	STS path signal label to designate equipped versus unequipped STS signals. Unequipped means the line connection is complete but there is no path data to send. For equipped signals, the label can indicate the specific STS payload mapping that might be needed in receiving terminals to interpret the payloads.
G1:	Status byte sent from path terminating equipment back to path originating equipment to convey status of terminating equipment and path error performance.
F2:	64Kbps channel for path user.
H4:	Multiframe indicator for payloads needing frames that are longer than a single STS frame; multiframe indicators are used when packing lower rate channels (virtual tributaries) into the SPE.
Z3-Z5:	Reserved for future use.

Table 2: STS-1 Overhead Bits

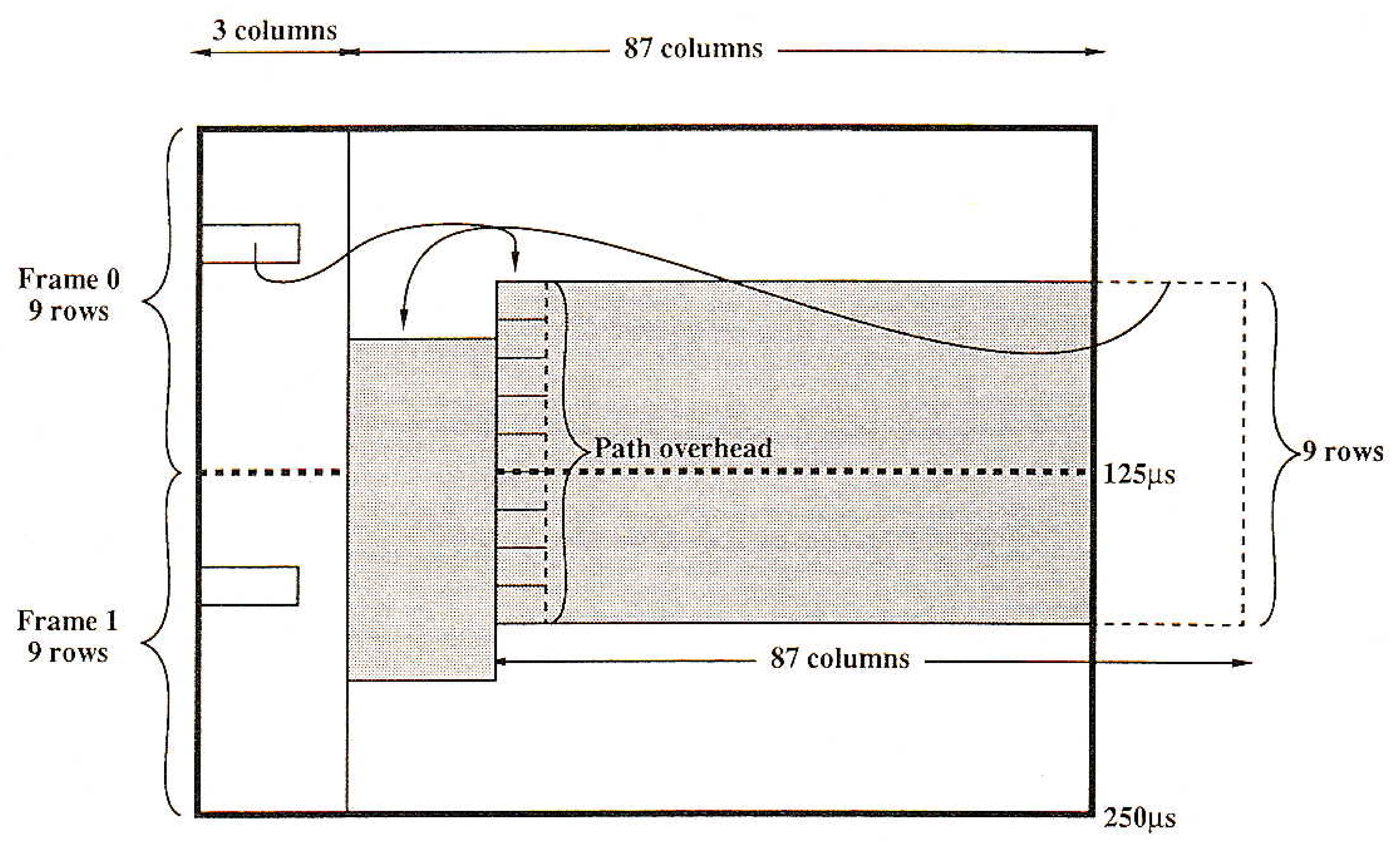

Figure 4: Representative Location of SPE in STS-1 Frame

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SONET *(continued)*

Timing

Because even the best atomic timing sources can differ by small amounts, SONET is faced with coping with the resulting timing differences. Each node must recalculate the pointer to alert the next receiving node of the exact location of the start of the payload. Thus, the payload is allowed to slip through an STS-1 frame, increasing or decreasing the pointer value at intervals by one byte position.

If the payload rate is higher than the local STS frame rate, the pointer is decreased by one octet position so that the next payload will begin one octet sooner than the earlier payload. To prevent the loss of an octet on the payload that is thus squeezed, the H3 octet is used to hold the extra octet for that one frame (Figure 5a).

Similarly, if the payload rate lags the frame rate, the insertion of the next payload is delayed by one octet. In this case, the octet in the SPE that follows the H3 octet is left empty to allow for the movement of the payload (Figure 5b).

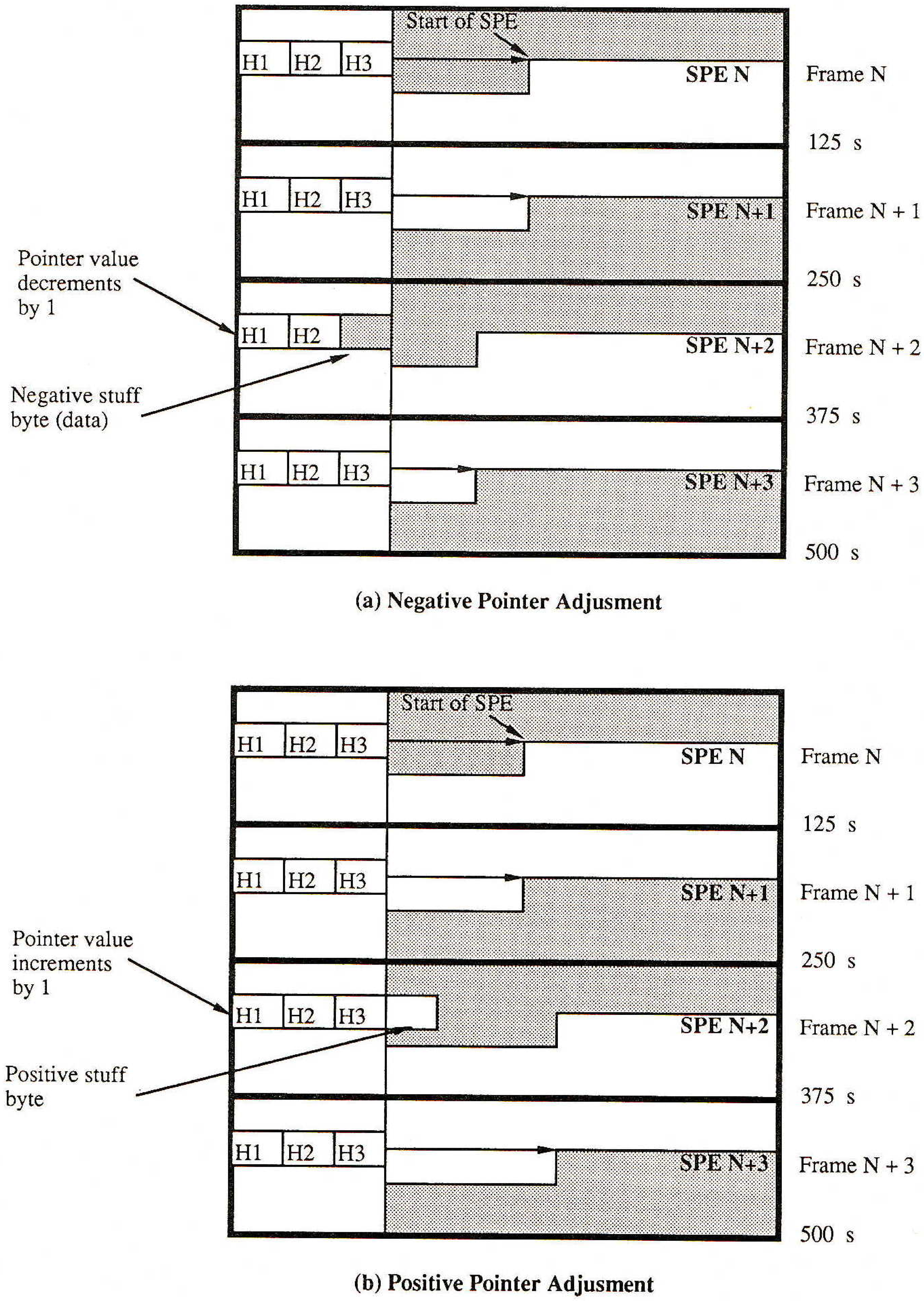

Figure 5: STS-1 Pointer Adjustment

Transmission of ATM cells

SONET can be used to carry synchronous payloads. In this role, it can be seen as the logical follow-on to today's high-speed synchronous wide-area telecommunications services, such as T-1 and T-3. But SONET has another important role to play, and that is as the backbone carrier for broadband ISDN (B-ISDN) traffic.

B-ISDN specifies that ATM cells are to be transmitted at a rate of 155.52Mbps or 622.08Mbps. As with ISDN, we need to specify the transmission structure that will be used to carry this payload. For 622.08Mbps, the matter has been left for further study. For the 155.52Mbps interface, two approaches are defined in I.413: a cell-based Physical layer and an SDH-based physical layer. We examine each of these approaches in turn.

Cell-Based Physical layer

For the cell-based physical layer, no framing is imposed. The interface structure consists of a continuous stream of 53-octet cells.

Since there is no external frame imposed in the cell-based approach, some form of synchronization is needed. Synchronization is achieved on the basis of the *header error control* (HEC) field in the cell header. The procedure is as follows (Figure 6):

- In the HUNT state, a cell delineation algorithm is performed bit-by-bit to determine if the HEC coding law is observed (i.e., match between received HEC and calculated HEC). Once a match is achieved, it is assumed that one header has been found, and the method enters the PRESYNCH state.
- In the PRESYNCH state, a cell structure is now assumed. The cell delineation algorithm is performed cell-by-cell until the encoding law has been confirmed *d* times consecutively.
- In the SYNCH state, the HEC is used for error detection and correction. Cell delineation is assumed to be lost if the HEC coding law is recognized as incorrect *a* times consecutively.

The values of *a* and *d* are design parameters. Greater values of *d* result in longer delays in establishing synchronization but in greater robustness against false delineation. Greater values of *a* result in longer delays in recognizing a misalignment but in greater robustness against false misalignment.

OAM

Finally, ATM cells are used to convey *Operations, Administration, and Maintenance* (OAM) information. A virtual path identifier of 0 and a virtual channel identifier of 9 identifies OAM cells.

The advantage of using a cell-based transmission scheme is the simplified interface that results when both transmission and transfer mode functions are based on a common structure.

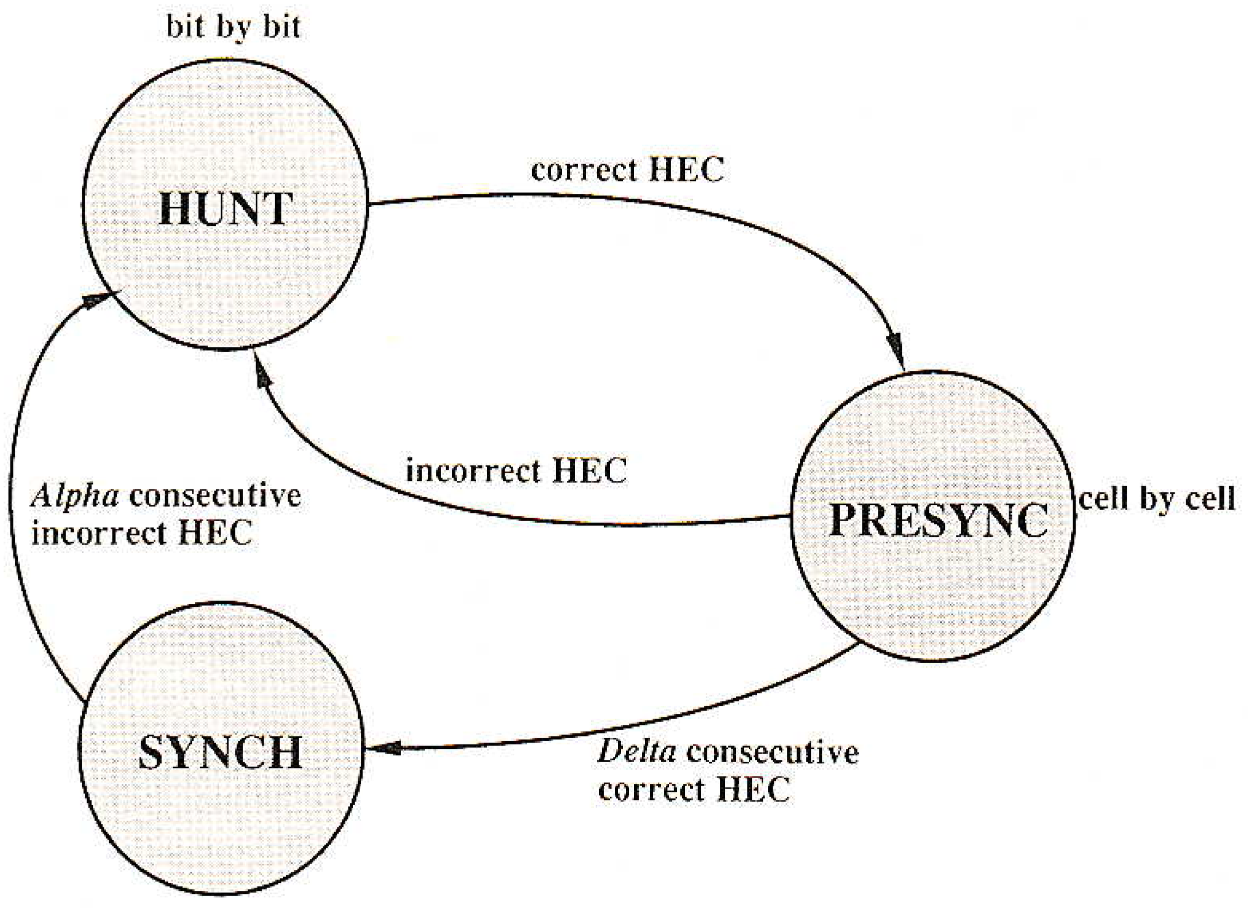

Figure 6: Cell Delineation State Diagram

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SONET *(continued)*

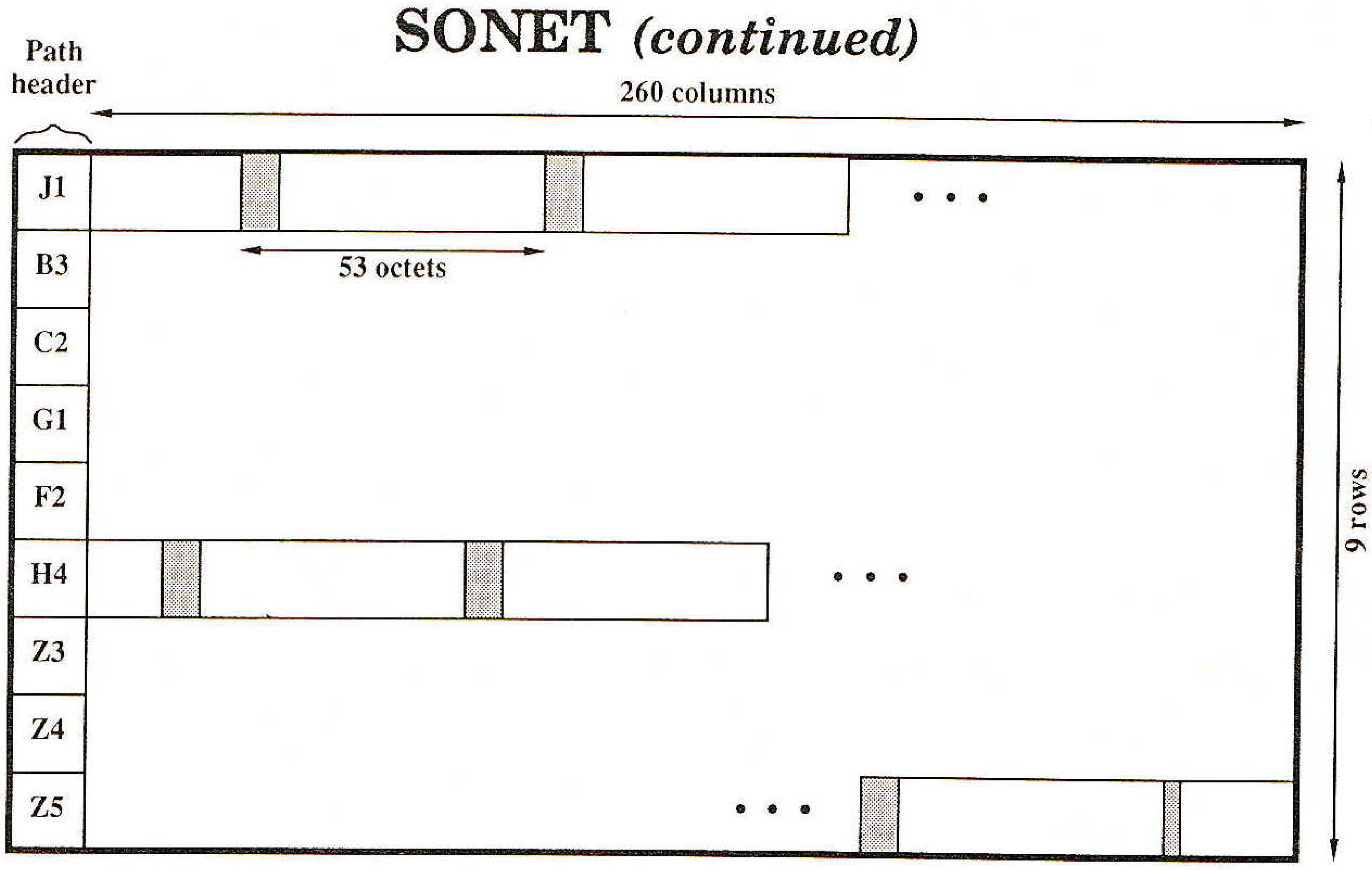

Figure 7: STM-1 Payload for SDH-Based ATM Cell Transmission

SDH-based Physical layer

For the SDH-based physical layer, framing is imposed using the STM-1 (STS-3) frame. Figure 7 shows the payload portion of an STM-1 frame. This payload may be offset from the beginning of the frame, as indicated by the pointer in the section overhead of the frame. As can be seen, the payload consists of a 9-octet path overhead portion and the remainder, which contains ATM cells. Since the payload capacity (2,340 octets) is not an integer multiple of the cell length (53 octets), a cell may cross a payload boundary.

The H4 octet in the path overhead is set at the sending side to indicate the next occurrence of a cell boundary. That is, the value in the H4 field indicates the number of octets to the first cell boundary following the H4 octet. The permissible range of values is 0 to 52. The advantages of the SDH-based approach include:

- It can be used to carry either ATM-based or STM-based (synchronous transfer mode) payloads, making it possible to initially deploy a high-capacity fiber-based transmission infrastructure for a variety of circuit-switched and dedicated applications, and then readily migrate to the support of B-ISDN.
- Some specific connection can be circuit-switched using an SDH channel. For example, a connection carrying constant-bit-rate video traffic can be mapped into its own exclusive payload envelope of the STM-1 signal, which can be circuit switched. This may be more efficient than ATM switching.
- Using SDH synchronous multiplexing techniques, several ATM streams can be combined to build interfaces with higher bit rates than those supported by the ATM layer at a particular site. For example, four separate ATM streams, each with a bit rate of 155Mbps (STM-1), can be combined to build a 622Mbps (STM-4) interface. This arrangement may be more cost-effective than one using a single 622Mbps ATM stream.

Summary

SONET has been developed as a synchronous transmission service for very high-speed facilities. It is a follow-on to today's services, such as T-1 and T-3 and, in addition, can be used to multiplex such lower-speed synchronous traffic over a higher-speed line. Thus, the transition to SONET is natural. Users of existing T-1 and T-3 services will find SONET attractive as their requirements grow and as high-speed fiber-based facilities become available.

The other role for SONET is in support of broadband ISDN. B-ISDN is based on the use of an asynchronous cell transmission scheme. But SONET facilities can be used to carry B-ISDN cells as payload. The growing use of SONET in the coming years will thus help smooth the way to broadband ISDN.

[This article is based on material in Bill Stallings' *ISDN and Broadband ISDN,* Second Edition, ISBN 0-02-415475-X. © 1992 by Macmillan Publishing Company. Used with permission. —*Ed.*]

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Components of OSI: Asynchronous Transfer Mode (ATM) and ATM Adaptation Layers

by George Clapp and Mike Zeug, Ameritech Services

Introduction

A companion article in this issue of *ConneXions* [see page 2] provides an overview of Broadband ISDN (B-ISDN) and Asynchronous Transfer Mode (ATM). This article outlines the work on ATM Adaptation Layers (AALs), with emphasis on AALs for data transport, and relates this work to SMDS and to the IEEE 802.6 standard.

Service classes

Several AALs are being defined in support of the four services classes identified for B-ISDN, which are shown in Figure 1. (A Service Class X, which is direct access to the ATM layer, is also possible).

	Class A	Class B	Class C	Class D
Timing relation between source and destination	Required		Not Required	
Bit rate	Constant	Variable		
Connection mode	Connection-oriented			Connec-tionless

Figure 1: B-ISDN Service Classes

For example, service class A has a required timing relationship between the source and the destination, the bit rate is constant, and the connection mode is connection-oriented. The CCITT describes this service as "asynchronous and synchronous circuit transport," or "circuit emulation for constant bit rate signals," and it may be used to transport the existing telephony digital hierarchy. Class B is similar to class A with the difference that the bit rate is variable. A sample class B service is a variable-bit-rate video encoder. Classes C and D are connection-oriented and connectionless data, respectively.

ATM Adaption Layers

A set of functionality is required to "converge" the common ATM transport service to meet the requirements of the different service classes. This convergence sublayer is called the *ATM Adaptation Layer* (AAL), and a set of AALs, AAL1 through AAL4, are being defined within CCITT. An additional AAL, AAL5, is under development in the *Exchange Carrier Standards Association* (ECSA) T1S1.5 Working Group on B-ISDN. It is intended that the U.S. will propose AAL5 to CCITT for adoption in the 1996 recommendations. Figure 2 below depicts protocol stacks in which the different service classes are supported by a particular AAL. One should note, however, that this one-to-one mapping is not required by the standard.

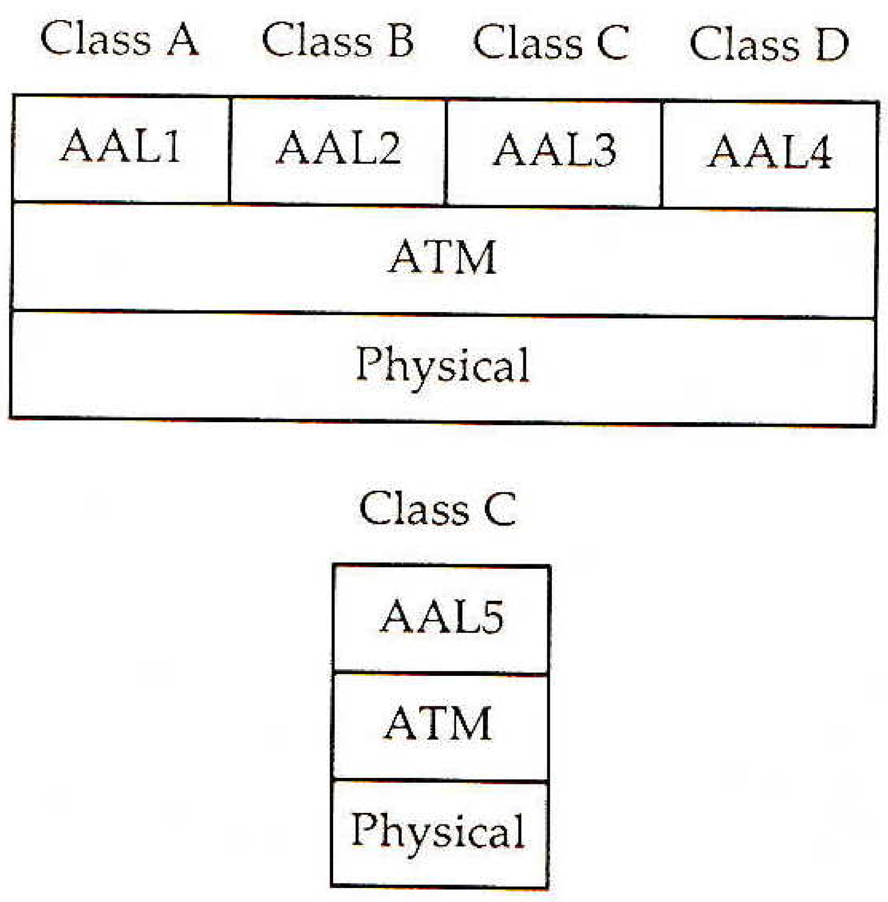

Figure 2: AAL1 through AAL5

A technical direction for AAL1 has been set and the procedures are presently under definition. Work on AAL2 is still in the early stages. This article will not discuss these AALs further, but will instead focus on AALs 3, 4, and 5, the AALs for data transport.

AAL 3 and 4

AAL 3 and 4 are intended to support connection-oriented and connectionless data transport, respectively. An early and continuing objective in the definition of these AALs was to have a common AAL for both connectionless and connection-oriented data. Consequently, AAL 3 and 4 are very similar. They have been subdivided into two sublayers, a *Convergence Sublayer* (CS) and a *Segmentation and Reassembly Sublayer* (SAR). Figure 3 shows how a variable length *Service Data Unit* (SDU) is treated by both AAL 3 and 4.

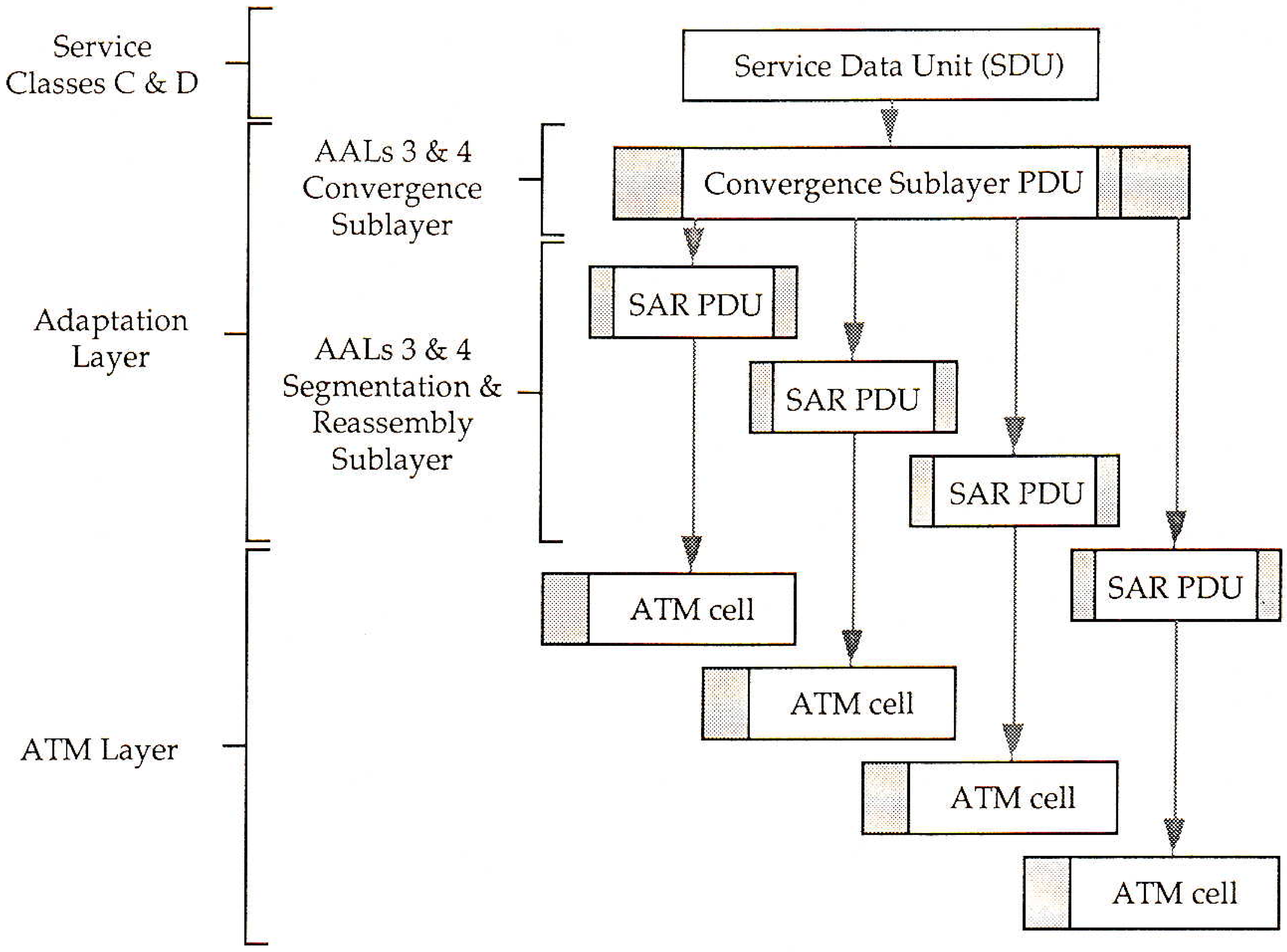

Figure 3: Treatment of an SDU by AAL3s and 4

A variable length SDU is first enveloped in a Convergence Sublayer header and trailer. It is then divided into 44-octet segments, each of which is in turn enveloped in a Segmentation and Reassembly Sublayer header and trailer, bringing the size of the SAR PDU to 48 octets. The SAR PDU is then inserted in the 48-octet payload of the ATM cell.

Convergence Sublayer

The Convergence Sublayer has in turn been subdivided into two further sublayers, the *Common Part Convergence Sublayer* (CPCS) and the *Service Specific Convergence Sublayer* (SSCP), as shown in Figure 4.

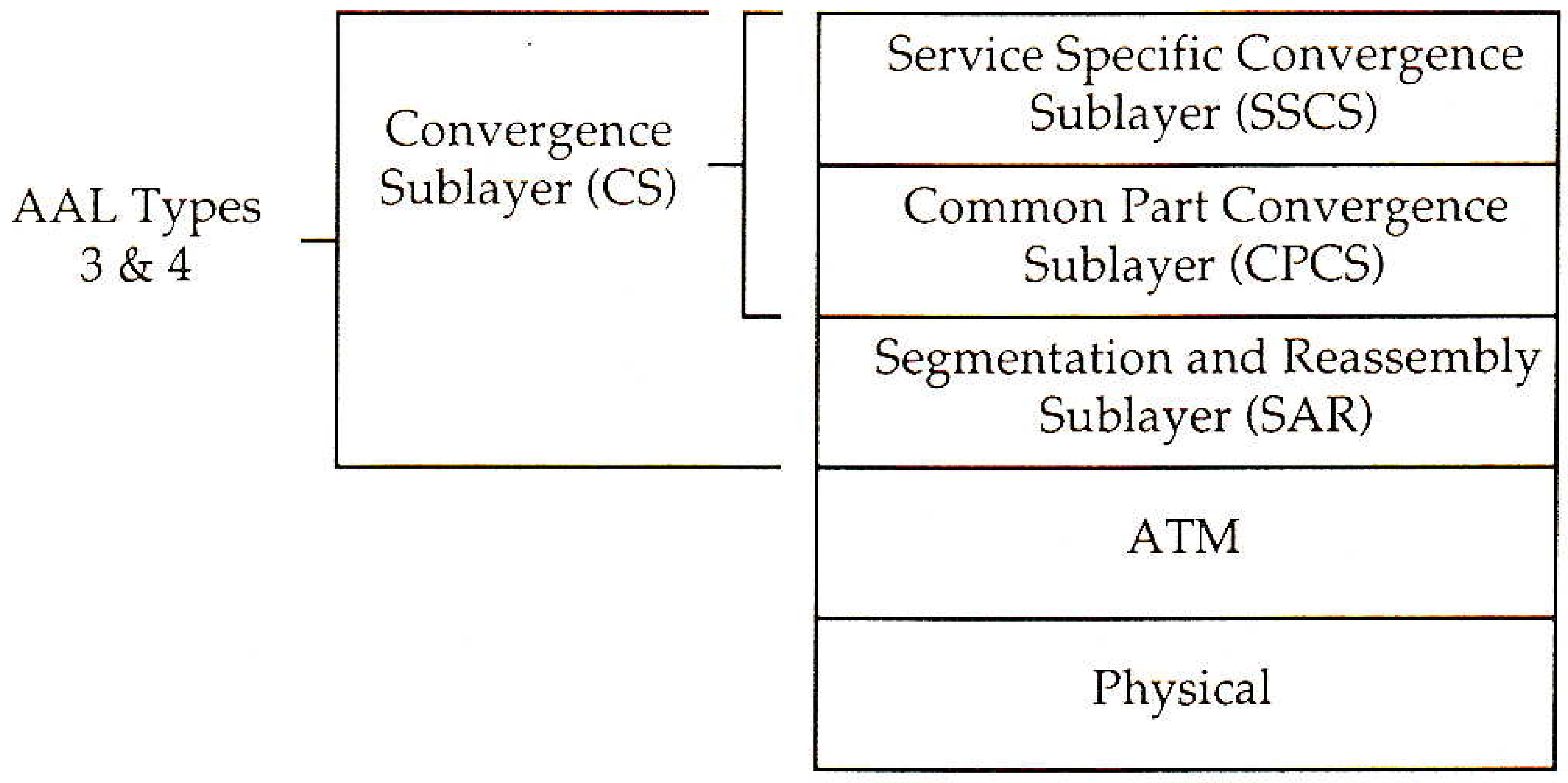

Figure 4. Sublayering of AALs 3 and 4

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Asynchronous Transfer Mode *(continued)*

The Common Part is the same for both AAL 3 and 4 in support of both connectionless and connection-oriented data. The Service Specific portion has additional functionality to support connection-oriented data. In effect, AAL 4 is AAL 3 with a null Service Specific Convergence Sublayer.

The United States has taken a well defined proposal on the Service Specific Convergence Sublayer for connection-oriented data to CCITT. However, agreement has not yet been reached, and there is very little text on the SSCS in the 1992 CCITT Recommendations. Consequently, this article shall now focus on the Common Part Convergence Sublayer in support of connectionless data, which is more fully defined.

Common Part Convergence Sublayer

The primary function of the CPCS is to provide mechanisms for error control. Figure 5 depicts the protocol structure of the CPCS header and trailer.

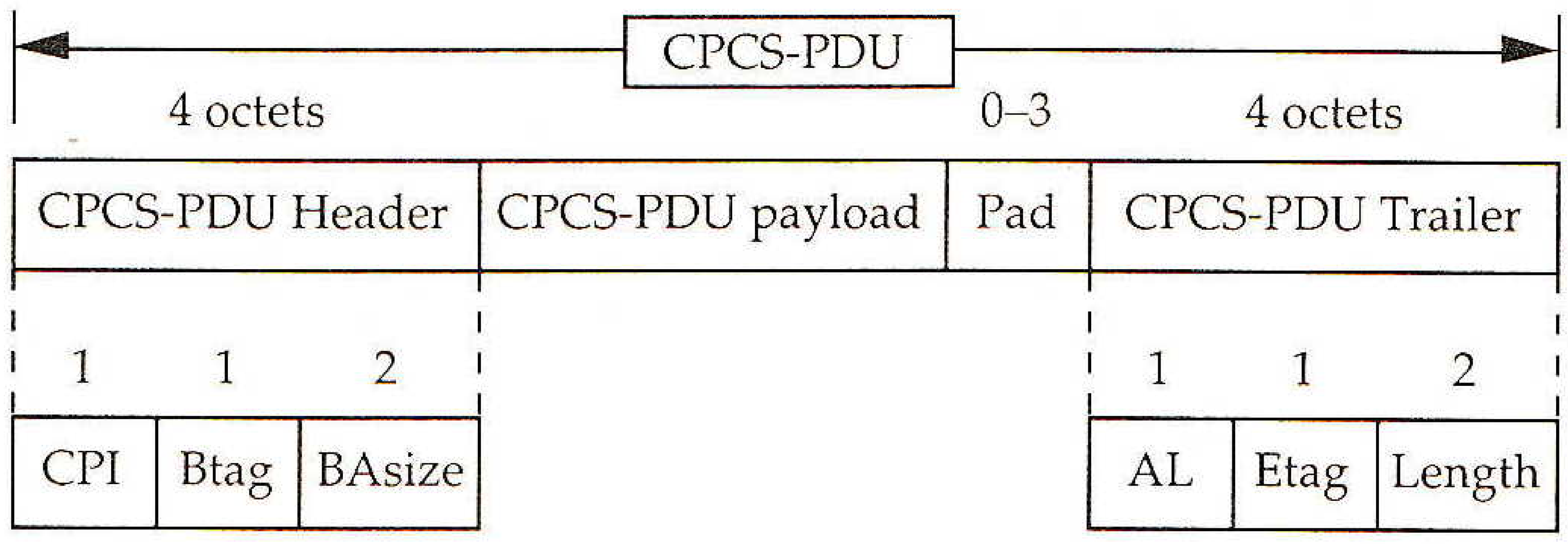

Figure 5. CPCS-PDU format

A 4-octet header and trailer is placed around the payload of the CPCS-PDU, with a Pad of length 0, 1, 2, or 3 octets inserted after the payload to align the trailer to a 4 octet boundary. This is done to facilitate 32-bit processing in implementations.

CPCS-PDU header

• *Common Part Indicator (CPI):* this field is used to determine the semantics of the subsequent fields of the CPCS-PDU. The value 0x00 has been allocated to identify the fields shown above (*Btag,* etc.)

• *Begin tag (Btag):* an error control field; an identical value is placed in the *Btag* and *Etag* fields and may be compared to associate the Beginning of Message (BOM) cell with the End of Message (EOM) cell.

• *Buffer Allocation Size (BAsize):* either the actual length of the CPCS-PDU payload or a maximum length. The field is used to inform the receiver of how much buffer space to allocate for the incoming packet. The value need not be the actual length. This is done to support pipelining, in which a filled SAR-PDU may be transmitted before the entire packet has been received.

CPCS-PDU trailer

• *Alignment (AL):* this field simply pads the trailer to 4 octets.

• *End tag (Etag):* the counterpart to the *Btag* of the header.

• *Length:* the length of the CPCS-PDU payload less the *Pad.* This field can be used to detect lost cells by comparing the value with the length of the received packet.

Segmentation and Reassembly Sublayer

The primary function of the SAR sublayer is to segment the variable length CS-PDUs into 44 octet blocks to be transported within the payload field of SAR-PDUs. In addition to segmentation and reassembly, the SAR supports error detection and multiplexing functionality. The structure of the SAR-PDU is shown in Figure 6.

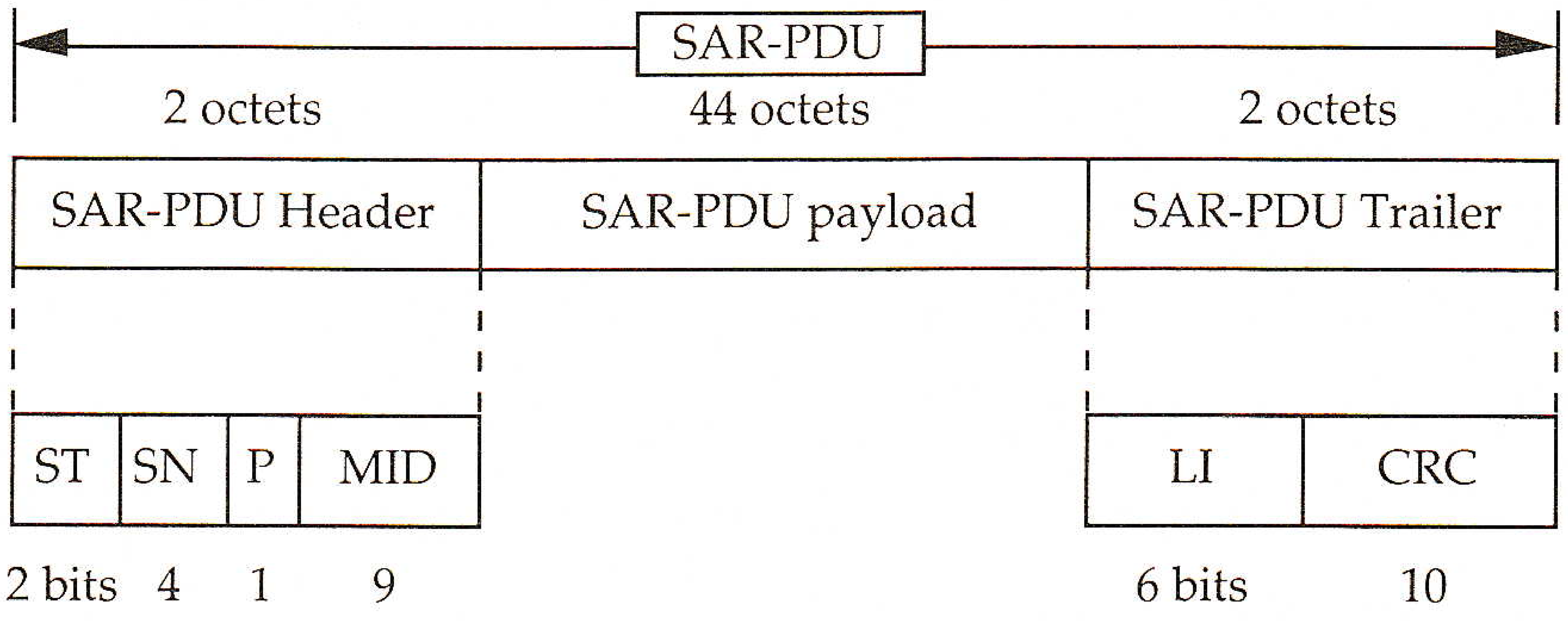

Figure 6. SAR-PDU format

The SAR layer for both AAL 3 and 4 place a two-octet header and trailer around the SAR SDU, creating a 48-octet SAR-PDU.

SAR-PDU header

• *Segment Type (ST):* this field delimits the variable length packets by indicating whether the segment is a Beginning of Message (BOM), Continuation of Message (COM), End of Message (EOM), or Single Segment Message (SSM). The ST values are generated at the segmentation machine and used by the reassembly machine to correctly reassemble the CS-PDU.

• *Sequence Number (SN):* a modulo 16 count used by the reassembly machine to detect lost or mis-inserted SAR-PDUs. The SN of each successive SAR-PDU of a CS-PDU will be incremented by one relative to the previous value for that data unit.

• *Priority (P):* this field is used by the transmitter to support the preemption of a CS-PDU by another CS-PDU on the same AAL connection. That is, the transmitter will stop transmitting the first upper layer message until the second (preempting) message has been completely transmitted. As an option, the transmitter may chose to interleave the two streams rather than completely suspending transmission of the first message. This field is supported only in AAL 3; it is coded to zero in AAL 4.

• *Message Identifier (MID):* for connection-oriented service (AAL3), this field is used to multiplex several AAL connections onto a single ATM layer connection. The usage of the MID differs from that of the priority bit in that the multiplexed streams belong to different AAL connections. For connectionless service (AAL4), the MID is used to associate the segments of a segmented packet.

SAR-PDU trailer

• *Length (LEN):* the number of octets in the SAR-PDU payload which contain user information. Its values may range from zero to 44. The SAR peer-to-peer procedures utilize the invalid length field coding of 64 to indicate that the transmitter is aborting a partially transmitted CS-PDU.

• *Cyclic Redundancy Check (CRC):* a CRC calculated over the entire SAR-PDU, excluding the CRC field. The generating polynomial used is:

$$G(x) = 1 + x + x^4 + x^5 + x^9 + x^{10}$$

Error detection

For error detection, AAL 3 and 4 use a 10 bit "per cell CRC" rather than a 32 bit "per frame CRC" (the CS-PDU does not contain a 32-bit CRC). This approach was taken for a number of reasons.

continued on next page

Asynchronous Transfer Mode *(continued)*

First, it was felt that performance would be better and implementation in silicon would be easier. With a 32-bit per frame CRC, one may calculate the CRC either on the reassembled CS-PDU or on the interleaved SAR-PDUs of a CS-PDU. If the calculation is done on the reassembled CS-PDU, one suffers a performance penalty since the CS-PDU cannot be delivered to the higher layer until the calculation is complete. If done on the interleaved SAR-PDUs, one must deal with the complexity of storing and recovering the partial CRC calculation for each SAR-PDU. In contrast, a per-cell CRC allows one to apply the CRC directly and simply, and to deliver the CS-PDU immediately upon reassembly.

Studies of the performance of the per-cell CRC convinced the standards groups that it fulfilled the relevant error specifications. Underlying these studies was an error model which was based on experienced errors on existing fiber transmission equipment, in which the dominant errors were either single bit errors or very long burst errors due to protection switching (switching from one transmission facility to another when the first is determined to be faulty).

AAL5

A recent development within B-ISDN is AAL5, which was first known as SEAL (*Simple and Efficient Adaptation Layer*). The proposal was taken to T1S1.5 in August 1991, and modifications to the ATM cell header necessary to support AAL5 were adopted by CCITT in Melbourne, Australia, in December 1991. In Figure 2, AAL5 is shown as supporting service class C, or connection-oriented data, but it may support class D, or connectionless data, as well.

In AAL5, packet delimiting is done within the ATM cell header rather than by the *Segment Type* field of the SAR-PDU header. Also, error detection is provided by a length field and a 32-bit per frame CRC rather than by a 10-bit per cell CRC. The treatment of a packet, or SDU, by AAL5 is shown in Figure 7.

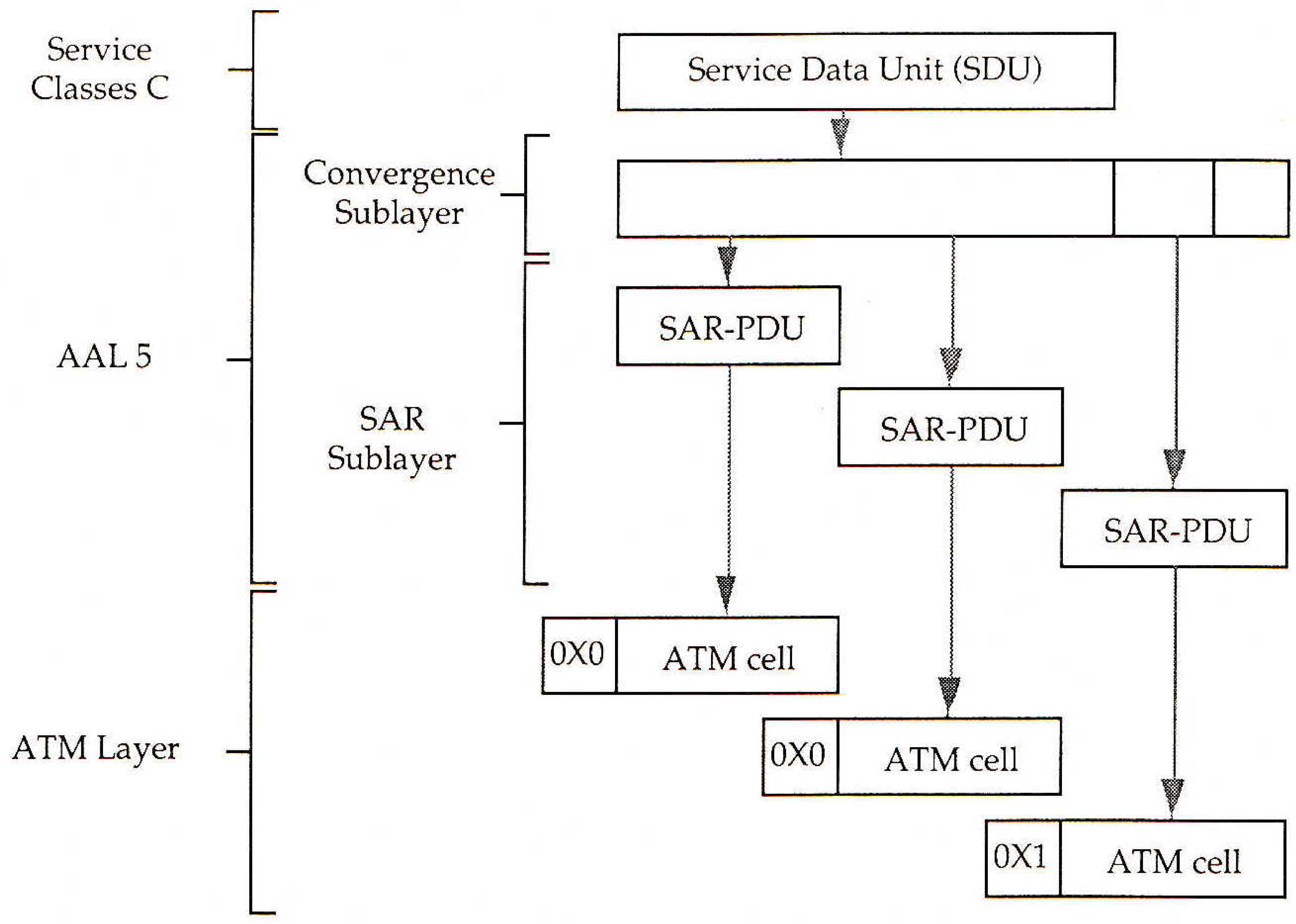

Figure 7. Treatment of an SDU by AAL5

The SDU is appended with a pad and an 8-octet trailer. The pad ensures that the AAL5 CS-PDU trailer is right justified within the last cell. The CS-PDU is then segmented and, although a SAR-PDU is shown, there is no SAR header and trailer.

The CS-PDU is simply segmented into 48-octet blocks which are directly placed in the payload field of the ATM cell. Finally, packet delimiting is performed by code points within the ATM cell header. As shown in Figure 7, a "0X1" indicates an End of Message (EOM) and a Beginning of Message (BOM) is indicated implicitly by the first "0X0" following an EOM. The format of the AAL5 CS-PDU is shown in Figure 8.

User Data	Pad	Control	Length	CRC32
	0–47 octets	2	2	4

Figure 8: AAL5 CS-PDU format

AAL5 CPCS-PDU trailer

- *Pad:* 0 to 47 octet pad which right-justifies the trailer in the EOM cell.
- *Control:* reserved for future standardization; presently coded to 0x0000.
- *Length:* the length in octets of the user data field (not including the trailer).
- *CRC32:* 32-bit CRC calculated over the user data, Pad, Control, and Length fields.

Error detection is provided by the Length field, which may be used to detect lost cells, and by the CRC32. For a given ATM connection, which is identified by a VPI/VCI value (*Virtual Path Identifier/ Virtual Channel Identifier*), segments of a particular CS-PDU are transmitted sequentially; segments of other CS-PDUs are not interleaved. However, a user may interleave the transmission of the segments of multiple CS-PDUs by using a separate VPI/VCI for each CS-PDU. Figure 9 shows a protocol stack frequently associated with AAL5 and an ATM LAN.

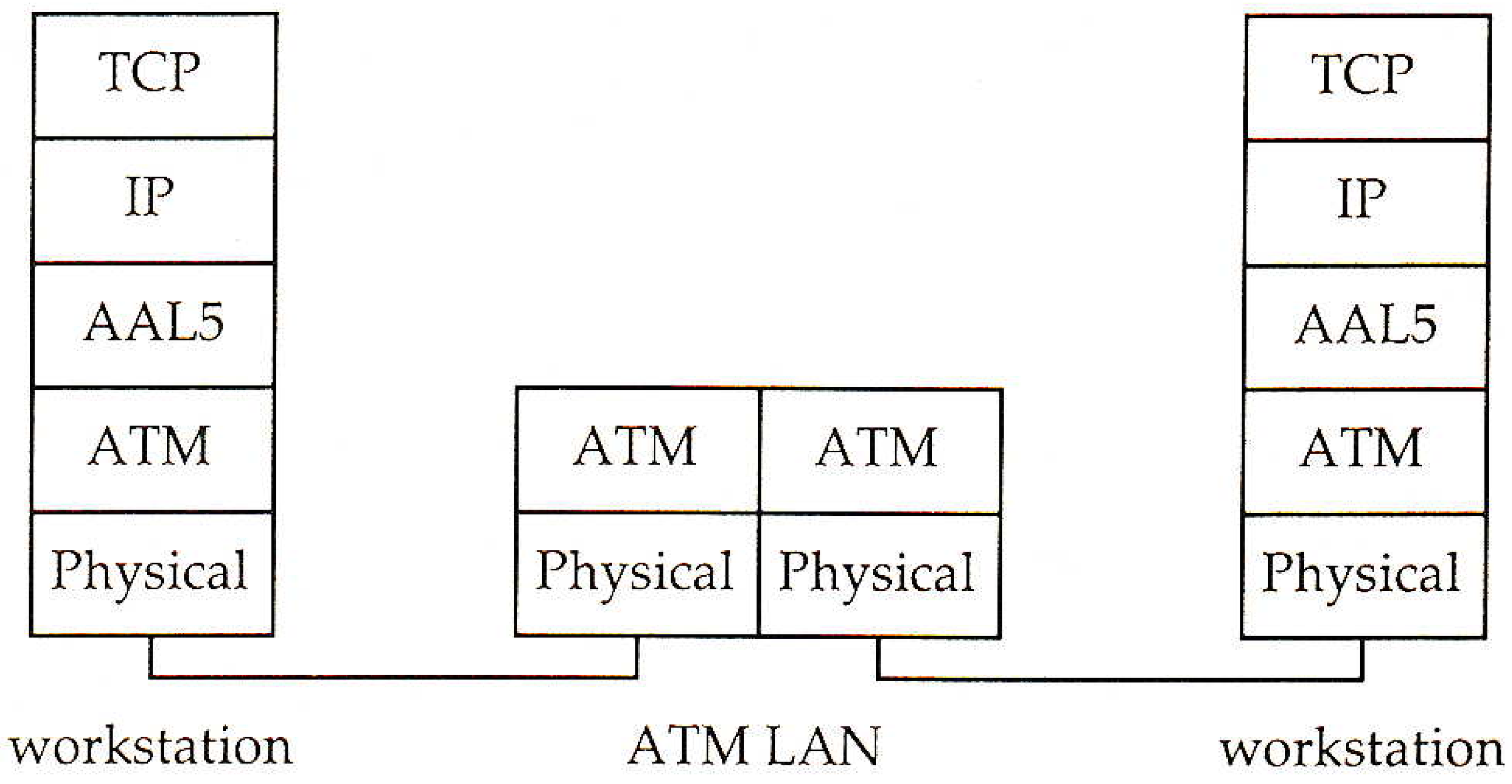

Figure 9: ATM LAN protocol stack.

The ATM LAN is a relatively small ATM switch (8x8 or 16x16 ports) with point-to-point links to a number of TCP/IP workstations. When workstations wish to communicate, an IP address is mapped to the VPI/VCI value of an ATM permanent virtual circuit (PVC), and the IP packet is inserted directly into AAL5 over the ATM PVC.

Modified ATM cell header

In order to delimit packets as done in AAL5, a modification in the ATM cell header was adopted by T1S1.5 and CCITT Study Group XVIII of CCITT, as shown in Figure 10.

continued on next page

Asynchronous Transfer Mode *(continued)*

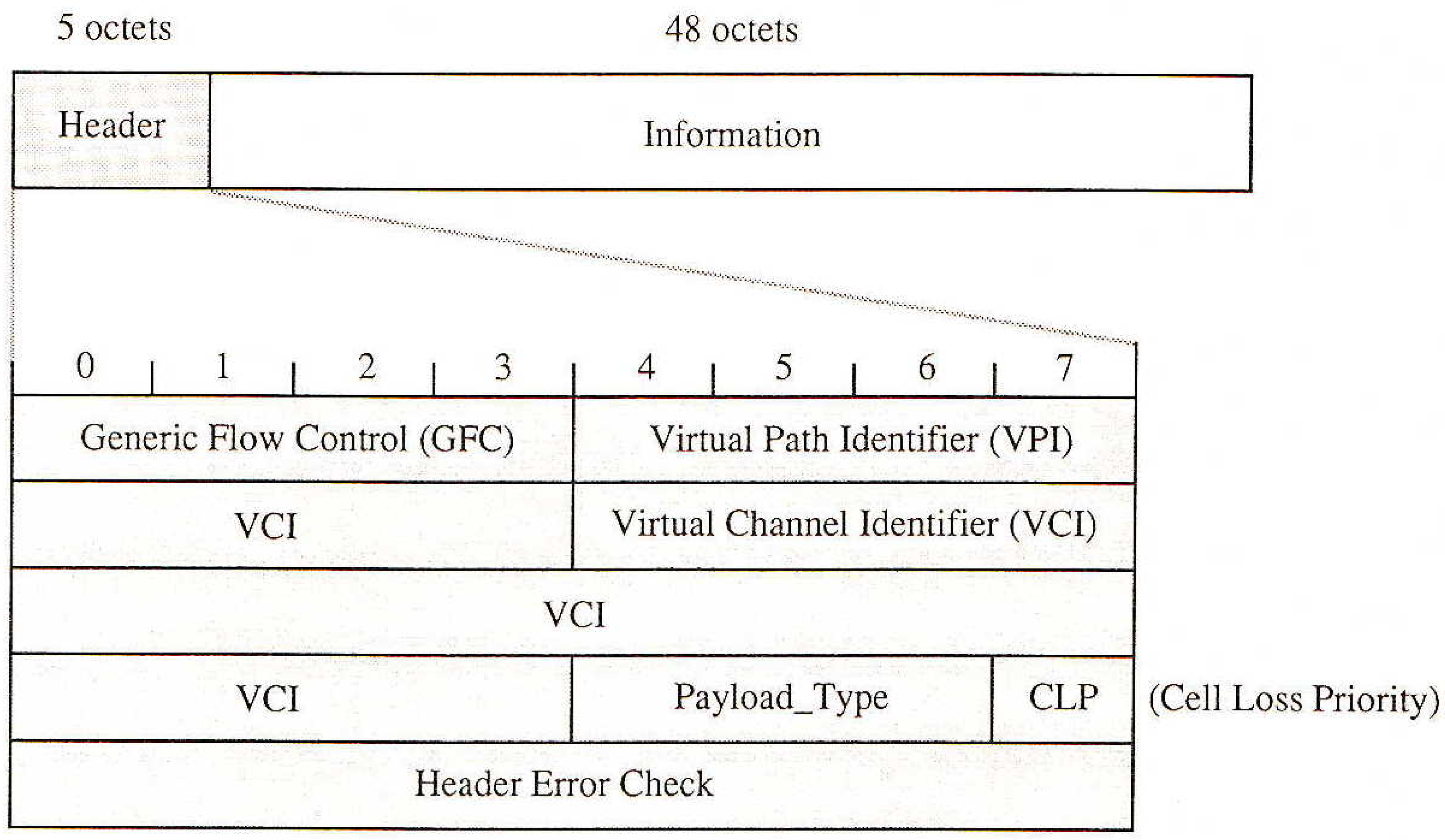

Figure 10. ATM cell format

The fields of the ATM cell header were described in the companion article (see page 10). However, a Reserved bit was added to the *Payload Type* field, and the following code points were allocated to the user:

000 User data cell, congestion not experienced, user indication = 0.

001 User data cell, congestion not experienced, user indication = 1.

010 User data cell, congestion experienced, user indication = 0.

011 User data cell, congestion experienced, user indication = 1.

The CCITT did not assign any semantics to the "user indication" values, but left this to user communities to define as they wish. It is anticipated that T1S1.5 will propose AAL5 for the 1996 CCITT Recommendations, and that "0X1" will indicate EOM and "0X0" will indicate "not EOM."

AAL4, SMDS, and IEEE 802.6

B-ISDN, SMDS, and the IEEE 802.6 standard on *Metropolitan Area Networks* (MANs) have been independent, parallel, and yet intertwined efforts. SMDS is defined in alignment with the IEEE Standard 802.6-1990 on *Distributed Queue Dual Bus* (DQDB) subnetworks. In turn, the 802.6 segment, segmentation and reassembly, and *Common Header* and *Trailer* correspond very closely to the ATM cell, SAR-PDU, and CS-PDU, respectively.

Recently, work has begun in CCITT SG XVIII on a broadband connectionless data service. This service has been designed to be equivalent to the MAC sublayer service described in ISO/IEC 10039 with enhanced capabilities. The protocol (named the *Connectionless Network Access Protocol,* CLNAP) is aligned with the connectionless protocol described in ISO/IEC 8802-6. The structure of the CLNAP is identical to the protocol structure found in IEEE 802.6 and SMDS.

While this work is not complete, the direction indicates a continued desire on behalf of SG XVIII to provide a seamless evolution of connectionless networks from MANs to B-ISDN.

References

[1] CCITT Temporary Document 39, Melbourne, Australia, December 1991, WPXVIII/8 Meeting Report—Annex 3 (Part 2), "Text of WP XVIII/8 B-ISDN Recommendations," Appendix 5, Draft Recommendation I.150, "B-ISDN ATM Functional Characteristics."

[2] CCITT Temporary Document 39, Melbourne, Australia, December 1991, WPXVIII/8 Meeting Report—Annex 3 (Part 2), "Text of WP XVIII/8 B-ISDN Recommendations," Appendices 9 & 10, Draft Recommendation I.363, "B-ISDN ATM Adaptation Layer (AAL) Specification."

[3] ANSI T1S1.5 / 91-449, "AAL5—A New High Speed Data Transfer AAL," November 1991.

[4] IEEE Standard 802.6-1990, "Distributed Queue Dual Bus (DQDB) Subnetwork of a Metropolitan Area Network (MAN)."

[5] Bellcore Technical Reference TR-TSV-000772, Issue 1, May 1991, "Generic System Requirements in Support of Switched Multi-Megabit Data Service."

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A Letter to the Editor

Ole,

You will find enclosed an object from Prague, Czechoslovakia that is rapidly becoming a collector's item. You are probably unfamiliar with *electronic mail license plates,* so please allow me to explain their purpose.

Until 1989, electronic mail in Czechoslovakia, as with other Eastern Bloc countries, was a sensitive technology. Access to even basic e-mail was carefully limited to high-ranking members of the Communist party. Multimedia messaging was strictly restricted to members of the Politburo and the Central Committee.

Throughout the country, the Computing Directorate of the Communist Party placed terminal clusters, used by officials to carry out their duties. It was always possible, however, that a member of the lümpenproletariat might wander in off the street and begin "hacking." Such a situation might well prove disastrous; you can well imagine the havoc that can be caused by excessive use of messaging systems.

To prevent such a situation, officials were issued e-mail license plates. Before using an account in a facility, the user would slip the license plate into the holder provided on the front of the terminal, allowing the e-mail police to quickly detect potential intruders.

The 1989 revolution did away with these relics of central control. Today, anybody with a leased line has access to modern messaging services and many of the e-mail police are awaiting trial.

—Carl Malamud

[Ed.: The enamel plate is reproduced full size above. Mr. Malamud is currently travelling the world to "explore the Internet."]

Book Reviews

ATM

Asynchronous Transfer Mode—Solution for Broadband ISDN by Martin de Prycker, ISBN 0-13-053513-3, 1991, 264 pp., Ellis Horwood publisher, series in Computer Communications and Networking.

There are very few books on ATM and BISDN yet, so I received this book with eager anticipation.

Organisation

It is divided in 6 chapters, roughly as follows

- *Evolution towards an Integrated Broadband Communications Network:* Describes where we were with circuits, packets and so forth (losses, delays, throughputs etc), and outlines the steps towards the ATM parameters (cell sizes, loss rates etc.).
- *Transfer Modes:* Justifies the packet mode rather succinctly. Also tries to justify Virtual Path and Circuit...
- *ATM by CCITT (The Gospel according to SG XVIII):* This is a bit short on the Adaptation layers for my interests, but given when this book was written, it is hard to see how it could be otherwise.
- *ATM switching:* This is a very good (although partial) introduction to different switches, fabrics and so on—the section on input versus output queuing is good.
- *ATM and terminal services:* This seems to be typically Telecommunications Industry oriented, with little consideration of direct Computer Attachment to the B-ISDN services (which is relegated to being via LAN/MAN in the next chapter only). However, the notes on Variable Bit Rate video codecs (and particularly the references) were useful.
- *MANs and High Speed LANs:* FDDI, DQDB and Orwell (with a brief mention of the Cambridge Fast Ring...)—fairly standard stuff—not enough on the problems of channel management when using a circuit (charged) service to interconnect datagram (free) *local* nets. The estimates of workstations speeds seemed reasonable to me.

Useful introduction

Overall, a useful text as an introductory read to get up to speed, necessarily biased slightly towards the telecommunications industry, but for all that, a very timely contribution.

B-ISDN

ISDN and Broadband ISDN (2nd Edition), William Stallings, Macmillan, 1992, ISBN 0-02-415475-X.

Revision

Before covering any details, I should note that this is a revision of Stallings' introductory text on (Narrow Band) ISDN. To this end it is:

- An introductory text—i.e., suitable for undergraduate classroom or technical managers more than engineers.
- Not detailed on ATM or B-ISDN in the manner of "Asynchronous Transfer Mode—Solution for Broadband ISDN" by Martin de Prycker (see separate review above) or Rainer Händel and Manfred Huber's "Integrated Broadband Networks—An Introduction to ATM-Based Networks." [Addison-Wesley, 1991, ISBN 0-201-54444-X]. (To be reviewed in a future edition).

Organisation

The book is in 3 parts. Part 1 is on "Integrated Digital Networks," part 2 is on ISDN (Narrow Band), and part 3 is on Broadband.

Part 1 (chapters 1–4) gives a reasonably good coverage of digital networks from the PTTs' point of view, detailing circuit and packet switching, address, call control, routing and congestion control, X.25 and fast packet, and multiplexing techniques.

Part 2 (chapters 5–11) covers the ISDN architecture, standards (very useful list), services (good on Teleservice Call Control/Progression stuff), MHS (for some reason—bit of a jump in levels), transmission structure and addressing, Physical+Link+Network layer protocols and interfaces, and finally Signalling System 7 (SS7). SS7 is not exactly ISDN, but it is what's in a lot of the phone system, and was designed to be the evolution path for quite a lot of telcos to get to ISDN, so it is useful and appropriate to detail this here. There are other technical solutions to getting ISDN services.

Part 3 (chapter 12 and 13) are a slightly disappointing short introduction to Broadband ISDN, and ATM. Chapter 12 is a "higher bandwidth, more services" version of chapter 1. Again, though, there is a useful list of standards. Chapter 13 is a good summary of the ATM structure. Cell formats are described, the VCI/VPI concepts, the various service classes and adaptation layers, the SONET and SDH STS hierarchy of signalling rates, and that's it. There is nothing on switching technology, call admission algorithms, or management in general of B-ISDN.

Appendices

Various appendices cover OSI concepts, flow control and so on, and a useful glossary, although I randomly tried finding "PDH" or the words "isochronous" or "plesiosynchronous" there or in the index to no avail.

One problem the book suffers from is diving from generality into details not especially relevant (e.g., in chapter 4 appendix 4b, a paragraph on a simple TV PCM encoding scheme). Another is that of US-centricity (e.g., SONET is one form of line transmission—there are others).

Finally, the book doesn't offer criticism of techniques that are described so as an undergraduate or manager I could not answer questions like "Should I get a 2 x 64Kbps leased line or basic rate ISDN?" (or emphasize the US/Europe difference—you couldn't get a 2 x 64Kbps line in the US, you'd have to get 2 x 56) or "Will I get Frame Relay and/or SMDS on B-ISDN, or will I be able to access raw cells?" and more importantly "What Call Control Protocol will I get on B-ISDN?" and "What global addressing scheme is likely to emerge?"

Comprehensive introduction

Overall though, a comprehensive introductory ISDN text. I'd say libraries should get it. I should certainly reference it as a basic text for students because of the breadth of coverage.

—Jon Crowcroft, University College London

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